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ABSTRACT

Three experiments tested whether qualitative differences in processing of verbal materials result from congenital hearing impairment. Subjects were children with reading levels equivalent to grades 4 to 6. Experiment 1 used repeated measurements with two modes of response and two kinds of cues; experiment 2 used acoustic similarity to produce interference with learning; experiment 3 presented word triads for short term retention. Results on the first two indicated that normal hearing subjects employed implicit acoustic features of printed materials while hearing handicapped subjects encoded the material using visual aspects. Also, the effects of auditory training were apparent, with its lack noted in the performance of children with very mild losses from 0 to 25 decibels. (Author/JD)

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FINAL REPORT

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MODALITY ASPECTS OF MEDIATION IN CHILDREN WITH NORMAL AND WITH IMPAIRED HEARING ABILITY

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DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

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Doris V. Allen

Wayne State University

Detroit, Michigan

December, 1969

The research reported herein was performed pursuant to a grant with the Bureau of Education for the Handicapped, U.S. Office of Education, Department of Health, Education, and Welfare. Contractors undertaking such projects under government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official position of the Bureau of Education for the Handicapped.

Department of Health, Education, and Welfare

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SUMMARY

The basic hypothesis tested was that qualitative differences in processing of verbal materials result from a congenital hearing impairment. It was postulated that normal-hearing subjects employ implicit acoustic features of printed materials while hearing-handicapped subjects encode the material using visual aspects. Two experiments were designed to test this hypothesis. A third experiment measured the relative efficiency of normal-hearing and defective-hearing subjects in short-term memory for word triads. Children with a reading level equivalent to grades 4-6 served as subjects for all three studies.

Experiment 1 used repeated measurements with two modes of response (oral and written) and two kinds of cues (auditory and visual). Paired-associate lists were used which consisted of either rhyming S-R pairs which were spelled differently (auditory cues) or S-R pairs which were spelled similarly but pronounced differently (visual cues). All presentations were visual. Five categories of hearing ability were tested. A significant effect due to cues and a significant interaction between cues and hearing ability were obtained. Visual cues were easier than auditory. The interaction was due to auditory cues being more difficult for all hearing-loss groups than for normal-hearing subjects.

Experiment 2 used acoustic similarity to produce interference with learning. Two paired-associate lists were created using identical materials but varying the manner of pairing. One list had consistent (C) pairings in that rhyming stimuli had rhyming responses while the other list had inconsistent (I) pairings which did not follow that pattern. Subjects varying in hearing ability from very mild losses to profound losses were tested. The regression of performance upon hearing loss was significant for C but not for I. Rather than producing interference, the rhyming dimension in C facilitated learning as a function of increasing hearing loss.

Experiment 3 presented word-triads for short-term retention over intervals up to 18 seconds filled with counting activity. Five groups of hearing ability were used. None of the groups differed on this task; delays were the only

significant source of variance. Furthermore, the data indicate that all groups of children used demonstrated a limited memory capacity consistent with other studies.

The results supported the hypothesis that differences exist in the manner in which normal-hearing and impaired-hearing children process printed verbal material. The effects of auditory training were apparent and the lack of such training with those having very mild losses (0-25 dB, ISO) was noted in their performance; it was recommended that auditory training be provided these children as well. Even with such training the child with a hearing loss does not become "normal," however. The implications of the demonstrated qualitative differences for the education of the hearing handicapped were discussed. These findings suggest that the retarded language skills of the hearing-impaired may respond to different teaching methods designed to use their unique cognitive development.

CHAPTER I

INTRODUCTION

The basic problem under investigation is the possibility that qualitative differences may exist in the way that hearing-impaired persons process verbal material internally as compared with persons having normal hearing. It is well known that congenital hearing impairments result in serious deficits in language skills. The typical deaf person usually acquires reading skills equivalent to only about the fourth grade level in spite of all our educational efforts. Even mild hearing losses can retard language development; this retardation is reflected in reading and is thus carried over to all academic areas (Goetzinger, 1962; Goetzinger, Harrison, & Baer, 1964).

There are many studies which indicate that the hearing-handicapped are not retarded intellectually but are deficient in those areas which are language dependent (Ewing, 1957; Furth, 1966). Gaeth (1963, 1966) found the deaf performed as well as or better than normal-hearing children on paired-associate tasks employing nonmeaningful-nonverbal visual stimuli. Templin (1948) demonstrated that the deaf have superior spelling skills in spite of their verbal deficiencies. Studies such as these suggest that the hearing-handicapped person is competent and fully able to perform up to normal standards where language does not enter into the task either explicitly or implicitly.

It is possible that the difference seen in language performance as a function of hearing ability may be one of kind and not of degree. The normal-hearing person develops speech at about two years of age. All of his interactions with his environment from then on involve this new behavior. The deaf child, on the other hand, does not acquire speech until some years later when he is formally introduced to it. During the intervening period of time, the deaf child has presumably observed and "thought about" his environment but has had to develop his own system for this internal manipulation of stimuli in contrast to the hearing child who can use language for this purpose (Myklebust, 1964).

Perhaps defining the major difference between verbal and nonverbal thinking will aid in understanding this distinction in covert processes. Verbal thinking uses symbols which are meaningful and are equivalent to speech; nonverbal thinking employs other symbols which are also meaningful to the individual but along a different dimension. This dimension might be idiosyncratic, i.e., unique to each individual in many instances. The thinking process can be characterized as one of categorization and generalization; in these respects verbal and nonverbal thinking are the same but the specific classes or categories which are used differ in the two kinds of thinking. Verbal thinking becomes more predominant as language develops since it is both more efficient for higher-order abstracting ability and also, probably, because it is more directly related to our mode of communication. Nonverbal thinking is purely subjective and cannot be communicated until some translation to verbal dimensions is accomplished. Certainly, an isomorphic relationship is not anticipated between verbal and nonverbal categories, thereby rendering "translation" difficult.

It may be that the hearing-impaired child begins with nonverbal thinking processes and, after learning language, adopts verbal thinking of a different form from that used by the child with normal hearing. The deaf child may retain the basic sensory dimensions of his original thinking processes and so respond to these new symbols in an old way; i.e., he may view them as visual-verbal elements rather than as aural-verbal. If so, the limited verbal skills of the hearing handicapped are to be expected since their primary means of manipulating information covertly would be either nonverbal or visually verbal. The latter can be translated into communicable symbols but with reduced efficiency when compared with translating auditory verbal thinking into speech. Thus, the hearing-impaired child who learns language may still not be identical with the normal-hearing child in thought processes, and this difference could account for the poorer performance on tasks designed to measure verbal skills.

The theory that thinking is internalized speech is not new. Developmental psychologists (e.g., Vygotsky, 1962) point to the natural progression seen in the child from overtly verbalizing all his activities to a subvocal and finally, presumably, an implicit verbalizing which becomes less detailed with further development. Certainly the adult who is learning a difficult task frequently regresses to the stage where he laboriously verbalizes the various steps in the sequence to monitor his own activities. Is all thinking merely internalized speech? This we cannot answer nor is the answer necessary for this study. Suffice it to say that at least some thinking---and particularly the kind of thinking which is concerned with verbal concepts---can be described in these

terms. Since verbal thinking is closely involved with communication of ideas, one might conjecture even further and say that much of the thinking which accompanies social communication is probably akin to internalized speech.

The auditory nature of memory has been inferred from empirical evidence. Gibson, Bishop, Schiff, and Smith (1964) studied both the perception and retention of verbal materials as a function of pronunciability and meaningfulness. Their data indicated that pronunciability was a better grouping principle for reading or coding to speech units; they concluded that "in the perception of _written_ language, the perceiver must code the stimulus material into units of _spoken_ language . . . ." (italics theirs). Murray (1966) has also aligned himself with this position. His study of the relationship between vocalization at presentation and recall using CVC trigrams led him to conclude that "a single store, probably auditory, was used for retention both for silently read and voiced material."

Sperling (1960, 1963, 1967, 1968) has developed a model for human information processing which also presumes that auditory coding is the key to memory. Visually presented material cannot be retained for periods longer than a second or two at most (Mackworth, 1963). Retention of visual materials for longer periods is accomplished, according to Sperling, by transforming the stimuli into auditory information and then rehearsing these as the stimulus traces decay. Thus, retention over longer intervals is dependent upon a rehearsal-auditory storage loop.

Numerous studies of short-term memory lend further support to the theory of an acoustic nature for "thinking." Conrad (1962) first reported that errors in short-term memory occur along a dimension of acoustic similarity. His finding has been verified and extended by many other studies (Baddeley, 1964; Conrad, 1964; Conrad & Hull, 1967; Dale, 1964; Laughery & Pinkus, 1966; Pinkus & Laughery, 1967; Wickelgren, 1965a, 1965b), so that it is a well-accepted phenomenon.

Not everyone is in complete agreement with the supposed acoustic nature of thinking or memory, however. Hebb (1968), for instance, stated that "it may be wrong to make a dichotomy between visual imagery and thought, or to identify abstract ideas with verbal processes." And Norman (1968), in constructing a theory of memory and attention, hypothesized that access to stored information can be made directly from a sensory code. Thus, presumably, visual verbal material (i.e., written language) would be stored differently from aural verbal input (i.e., spoken language). Posner and Keele (1967) felt that visual information can be preserved

if subjects "desired to do so." Hintzman (1965) presented data which he interpreted as supporting "kinesthetic feedback produced by subvocal rehearsal" rather than aural encoding in short-term memory. However, Wickelgren (1969) pointed out some theoretical flaws in that work and concluded that no clear answer is yet available. Cole, Haber, and Sales (1968) also studied this problem and concluded that manner of articulation is more important but not separable from acoustic cues for coding. Bregman (1968) found graphic cues to be superior to phonetic cues for recall following short delays. For longer delays semantic cues were best, a finding consistent with many other studies of the role of meaningfulness in long-term memory.

The latter point requires some clarification as it superficially seems contradictory to the basic thesis of this study. Meaningfulness is by far the most compelling dimension affecting long-term retention. Short-term memory, on the other hand, seems to be primarily acoustic in nature if the weight of experimental evidence is considered.

The relationship between short- and long-term memory is another theoretical issue. Some, e.g., Hebb (1961), believe that the two kinds of memory exist along a continuum and that all information must pass through short-term memory before entering long-term memory. Others, e.g., Waugh and Norman (1965), postulate two separate mechanisms and theorize that information can enter either or both. Melton (1963) reviewed much of the evidence for the two positions and concluded that the evidence favors a single-factor theory of memory. Temporally, Mackworth (1964) has designated five minutes as the limit for short-term memory; longer intervals of retention involve long-term memory.

For our purposes, it may be hypothesized that acoustic attributes facilitate acquisition of verbal materials but further "internal processing" occurs under requirements for longer retention so that the information is then stored according to meaningfulness. Indirect support for this position is seen in _klang_ responses made by schizophrenics in word association tasks, made by young children (Entwisle, 1966) and by normal subjects under conditions of distraction (Eagle & Ortof, 1967). In other words, the initial response or reaction to verbal stimuli appears to be made on the basis of its sound, at least under certain conditions.

Given, then, that mental processing might be characterized as auditory in normal-hearing persons, it was hypothesized that congenital hearing impairments, even if only slight, could modify the efficiency of the auditory channel for information input so that the individual would not develop cognitively in the same manner. Rather than using

faulty auditory information, the hearing-impaired individual probably relies more heavily upon the other senses for gaining knowledge of the world about him. It is assumed that the prelinguistic hearing child may also show these same tendencies but language soon becomes a more important dimension for him. The behavior of relevant members of his environment is primarily verbal and so he lays down a mental language base which reflects this (Fry, 1966). This mental language base is auditory in nature and is not altered during subsequent development since the auditory mode is also the most efficient way to process verbal material. The auditory mode involves fewer elements (or bigger "chunks") than does the written equivalent and so should be a better way of handling the same information (Miller, 1956).

The hearing-impaired child, on the other hand, is not able to gain as much information from auditory input even when exposed to the same environmental circumstances. Therefore, he tends to ignore or minimize the contributions of the auditory system for information gathering and continues to develop a mental orientation based upon other sensory dimensions. The learning of language by such children may be analogous to learning a second language by normal-hearing persons (Hirsh, 1966). The use of the second language is impeded by the need to translate everything back and forth from one system to the other. Proficiency is not really acquired until such translation is eliminated. In the same fashion, it is suggested that the person with a congenital hearing loss develops a cognitive structure which is primarily visual-tactile in its organization. He learns to "think" along these dimensions and fares well until he has to communicate what it is that he is thinking. Furth (1966) has demonstrated that deaf children are not deficient in their ability to think even though their verbal skills are limited. Their major handicap may be in the translation requirements from their own system to the one basic to communication.

Communication, other than the relatively small contribution made by gestural or nonverbal language, involves the use of a conventional symbol system which, in our culture, is primarily oral. Thus, the hearing-impaired individual has to search for suitable or equivalent labels for his thoughts before he can talk about them, or before the interaction of the language system and the semantic system can occur, as expressed by Jenkins (1966). If an idiosyncratic concept which the hearing-handicapped person generates has no corresponding label in our system, he cannot communicate that idea. An illustration of this is the confusion exhibited by a foreign college student some years back when required to respond to a personality test item involving the concept of embarrassment. The student was from Thailand and no such feeling was labeled in her native language. Therefore, she could

not appropriately respond since she could not identify the concept emotionally. Is the deaf child put in similar predicaments as he attempts to integrate his thoughts with the language system we give him for communication? Blanton (1965) has found the deaf to be weak in their emotional responses to words, adding weight to this position.

A number of studies comparing performance of normal-hearing and impaired-hearing groups lend support to the theory that qualitative differences in cognitive processes as a function of hearing ability may exist. For example, Conrad and Rush (1965) found that normal-hearing adults made acoustic errors (e.g., substituting E for G in recalling sequences of letters) in a short-term memory task; they further found that deaf adults also made consistent errors but along a dimension which they could not identify. Odom and Blanton (1967) studied phrase learning by deaf and normal-hearing children and concluded that the deaf process word phrases differently; they suggested that the linguistic structure of Sign might be more relevant. Two other studies by Blanton and his associates (Blanton & Nunnally, 1967; Blanton & Odom, 1968) demonstrated that the deaf were unaffected by the pronunciability ratings of items in contrast to the interference exhibited by difficult items upon normal-hearing performance. Youniss (1964) reported that the deaf were better than normals in performance on training trials in a study of concept transfer, although the groups did not differ on the transfer phase of the experiment. His finding was consistent with that of Furth (1961), and Youniss conjectured that the deaf subjects' "lack of verbal experience did not impede their using some other surrogate mechanism comparable to verbal mediating responses." Thus, it can be seen that a number of investigators have noted a qualitative difference in performance between normal-hearing and hearing-handicapped subjects. Some have speculated upon the nature of the difference while others have been more conservative and merely remarked upon the existence of a difference.

Finally, an unpublished study by M. Margaret Collins McLinden (1959) should be cited. Mrs. McLinden had been in the doctoral program at Wayne State University and had proceded through the stages of collecting and analyzing data for her dissertation when circumstances forced her to drop her studies. She administered paired-associate learning tasks to eight groups of children; normal-hearing from grades 4 and 6 and six groups of hearing-impaired representing different degrees of hearing loss. Four lists of word-pairs were learned by each subject; an unrelated list (e.g., MAN-SOUP), an "auditory" list (e.g., ROUGH-CUFF), a "visual" list (e.g., LOST-MOST), and a combined list (e.g., BOAT-COAT). All materials were presented visually, the terms "auditory" and "visual" were used only to designate the dimension of

similarity in the lists. She found that all six of the hearing-impaired groups learned the "visual" list faster than the "auditory" while the two normal-hearing groups learned the "auditory" list faster than the "visual." Not all of the differences were large enough to be statistically significant but the trend was uniform for the two categories of hearing ability, impaired and normal.

These findings were unexpected. It was not surprising to find that children with profound hearing losses performed differently from their normal-hearing counterparts but it was assumed that mild hearing losses would not affect performance in a similar fashion. These results suggest that all degrees of hearing impairment produce an altered approach to verbal material. The presence of even a slight hearing loss seemed to interact with cues for learning so that the rhyming cues became less compelling while cues of visual similarity contributed more to performance. The theory of qualitative differences between the thinking processes of normal and impaired-hearing persons received considerable support from these data. However, additional research was needed to determine both the reliability and the extent of these findings.

Certainly the demonstration of qualitative differences as a function of hearing ability has considerable educational significance. The limited verbal skills of the hearing-handicapped may be reflecting this more basic difference. If so, then drill or other similar educational methods would fail to rectify the problem since they are based upon a theory of quantitative differences, i.e., they view the difference in language skills as representing a retardation or immaturity in linguistic development. Qualitative differences would require entirely different approaches. One can either modify the procedures to maximize the use of thinking processes already established in the child or one can search for ways of changing this mental process to another that is more like that of normal-hearing children. Critical to this decision would be an evaluation of the comparable efficiency of the two systems.

As discussed previously, Sperling (1963) theorized that brief incoming stimuli are stored initially in a manner which retains the sensory properties of the stimulus. Visual stimuli enter visual information storage (VIS) and acoustic stimuli are held in auditory information storage (AIS). Fairly rapid decay characterizes both of these components of memory. The major functional difference between VIS and AIS is that information in auditory storage can be renewed by rehearsal. Rehearsal of visual information can also occur but it involves recoding the traces verbally. These transformed traces are then stored in AIS. Thus, the AIS-rehear-

sal loop is seen by Sperling as the limiting factor in immediate memory.

It might be assumed that deficits in auditory sensitivity would alter or modify these processes. Limited verbal proficiency might hamper the recoding-rehearsal steps. Congenital auditory deficiencies may result in a poorly developed AIS. Such individuals may have instead a highly efficient VIS and, furthermore, may have developed strategies for visual or nonverbal rehearsal. Some indication of this is seen in the Conrad and Rush study (1965) cited previously which found that deaf subjects did not make acoustic errors in short-term memory but did make systematic errors along some unidentified dimension.

A short-term memory study was included in the project to assess the effectiveness with which verbal information can be stored and retrieved following brief delays. Differences obtained in performance with such a task might be interpreted as reflecting qualitative and/or quantitative differences in these processes. Of particular interest here are possible differences in performance between normal-hearing and impaired-hearing subjects. Lack of performance differences between the two groups would not rule out differences in process but would suggest that variations in process are functionally unimportant. On the other hand, demonstration of performance differences as a function of hearing ability might have serious implications. As an extreme example, such findings may indicate that verbal material cannot be retained efficiently by some groups of subjects thereby rendering these individuals unable to respond to anything but the immediate verbal stimulus.

In summary, then, the basic purpose of this research was to test the hypothesis that qualitative differences exist between the thinking processes of normal-hearing children and children with some degree of hearing loss. Of particular interest is the group termed "hard-of-hearing," i.e., those with mild or moderate losses. The study by McLinden (1959) suggests that such children are more like "deaf children who can hear" rather than like normal children with reduced hearing ability. Again, verification of this would have implications for the education of children with such losses. At present they are integrated as much as possible into the normal classrooms. Perhaps this is not the best procedure without more orientation of both the child and the teacher to the problems associated with qualitative differences in the manner with which the two kinds of students attack verbal material.

A second goal of the project was to study the relative efficiency of the normal and hearing-impaired groups in

short-term retention of verbal material. Depending upon the outcome of the initial hypothesis, one might either conclude that qualitative differences do or do not exist. If qualitative differences are demonstrated, this experiment would gauge the functional equivalence of the two systems. If qualitative differences are not tenable, the relative skill of the two groups in using presumably the same system would be measured. In either case, information would be gained comparing the two kinds of hearing ability in this skill.

CHAPTER II

METHODS

Detailed information concerning Apparatus, Materials, Subjects, and Procedures will be discussed under separate headings as they pertain to the entire project. The separate experiments will contain only brief descriptions of methods, sufficient to maintain continuity and to identify variables.

Apparatus

The basic equipment used throughout all phases of this project included a Tel-n-See projector-tape recorder system and a lenticular screen. Another separate tape recorder and a metronome were used in certain portions of the research. A portable Beltone audiometer (Model 10D) was used to screen all subjects identified as having hearing losses.

All materials were presented visually only. The Tel-n-See instrument, manufactured by the Baptista Film Mission, uses a 16 mm film strip. Duration of film exposure is controlled by bursts of a 1000 Hz tone recorded on magnetic tape and played on the tape recorder built into the instrument. These tones activate relays which advance the film.

The stimulus words were prepared by using Art-Type, a dry transfer process. The letters were 48 point Helvetica Light, Capitals, in black and were transferred onto a white surface. These stimuli were then photographed with the Tak-n-See camera (an accessory of the Tel-n-See) using negative film. A reverse image was obtained in that the words were projected as white on a black background. Blank frames were entirely black which reduced problems associated with glare.

Oral responses were required of the subjects under certain conditions in Experiment 1 and throughout all of Experiment 3. These responses were recorded with either a Mercury or an Ampex Micro 85 tape recorder. Both are cassette units. Booklets were provided for written responses. A separate page was used for each trial. The metronome (Seth Thomas Electronic Metronome, Model E 962-000) was used to pace the

interpolated activity and to time the delay intervals in Experiment 3. This instrument provides both an acoustic and a visual signal.

All children assigned to the hearing-loss categories were screened at the time of testing using the Beltone audiometer. The data obtained were compared with other records of the child's hearing ability. Any discrepancies were noted at the time and resolved before the child was assigned to a particular hearing-loss category.

Materials

Paired-associate word lists were used in Experiments 1 and 2 while Experiment 3 used word triads and digits. All words were supposedly meaningful and familiar to the subjects. The words were drawn primarily from the set of monosyllabic words rated A or AA in frequency by Thorndike and Lorge (1944). The AA rating indicates 100 or more occurrences per million, while A means 50 to 99 occurrences per million. These words are recommended for vocabulary building in grades 1 through 3 and certainly should be in the vocabulary of grade 4 children. A few words with frequency ratings less than A were used in Experiment 1 in order to construct word pairs that conformed to other criteria. These less-frequent words were judged to be of sufficient familiarity to be meaningful to the subjects intended to be used in the study. Standardization data (see Appendix A) did not show any relationship between level of performance and lists containing these less frequent words, evidence that the words were in the vocabulary of the samples tested. All of the words used in Experiment 3 were monosyllabic with either A or AA ratings.

Experiment 1 used four lists of eight word-pairs. Two lists were designated "auditory" lists and consisted of stimulus-response pairs which rhymed but were spelled differently (e.g., WEIGH-PLAY). The other two lists, designated "visual," consisted of word-pairs which looked alike but sounded differently (e.g., LOVE-STOVE). The designations "auditory" and "visual" refer to the dimensions containing the cues for learning. The complete lists are presented in Appendix C. The equivalence of the two lists for each dimension was assessed by administering them to classes of grade 4 children prior to using them in Experiment 1. The standardization procedures and results are presented in Appendix A.

The two "auditory" lists from Experiment 1 were used to form lists for Experiment 2. The words were rearranged so that rhyming pairs were either both stimuli or both responses. These stimuli and responses were then associated to produce

either "consistent" or "inconsistent" pairings similar to the lists generated by Dallett (1966). Consistent pairings were those in which rhyming stimuli had rhyming responses, e.g., DOOR-SIGH and MORE-LIE. Inconsistent pairings had rhyming stimuli associated with non-rhyming responses, e.g., DOOR-SIGH and MORE-WHILE. The complete lists are presented in Appendix C.

A practice list consisting of four pairs of unrelated words was also used in individual testing for Experiments 1 and 2. The complete list is also given in Appendix C.

Experiment 3 used monosyllabic word triads, e.g., UP-BAG-GO, and two- or three-digit numbers. All of the monosyllabic A and AA words from the Thorndike-Lorge lists were used. The complete set of triads is presented in Appendix C.

Subjects

A total of 1365 children participated in this project, 1196 normal-hearing youngsters and 169 with varying degrees of hearing loss. Pilot studies to assess the suitability of timing intervals and other procedures used 38 normal-hearing children. All normal-hearing children were enrolled in grade 4 classes in either the Detroit Public Schools or suburban schools surrounding Detroit. The hard-of-hearing youngsters were found in some of these same schools and also in a local residential school for the deaf.

Normal-hearing. Children who were assigned to the normal-hearing category were tested either in intact classrooms (group testing) or individually. The classes used were considered a random selection from all grade 4 classes and the experimental conditions were assigned randomly with the restrictions that at least two classes receive the same condition and that the two classes not be from the same school. Following statistical examination of the data for the two classes, the results were pooled if such was permissible or another classroom was tested and the procedure repeated. A total of 41 intact classes was used which involved 1097 children. Grade 4 subjects who were used in individual testing were randomly selected from classes which had not participated in group testing.

Data from those children in group testing who did not understand the task were discarded. This decision was made upon examination of their response booklets. Evidence for lack of comprehension of the task itself was inferred from behavior such as writing down stimulus words rather than responses or writing down responses in the same order as

from the preceding learning trial. Data were not discarded merely on the basis of poor performance so long as the booklet indicated that the child was attempting to learn the task (or failed to indicate that the child was not so doing). No such problems were encountered in individual testing since the experimenter could verify that each child understood the task.

Reading levels for all children were obtained from school records and data for those children having a reading or vocabulary grade equivalent either above grade 6 or below grade 3.5 were not used in the study. The data from children reading at grades 3.5 through 6 were pooled since this represents, conservatively, the range of ability generally found in a grade 4 classroom. The decision to pool was based also upon independent evidence that adjacent grades do not differ significantly in performance on paired-associate learning tasks (Gaeth, 1963, 1966) and from evidence that grade 4 and grade 6 children do not differ on tasks similar to those used in this study. The unpublished data of McLinden (1959) showed that these two grades of normal-hearing children did not differ from each other in performance on the visual or auditory lists. The two grades differed only on the practice (unrelated) list but performed similarly on the subsequent three lists.

On the basis of her findings, it was decided to use a practice list in the project in order to bring all subjects to the same level of understanding of the task prior to collecting experimental data. The practice list was not used with group testing, however, since the amount of practice needed varied across individuals and any fixed number of trials would be arbitrary. Too much practice might also have some effect upon second-list learning.

Hearing-handicapped. Hearing-loss subjects were initially identified by the Special Education Directors of the various school systems. School records provided both hearing and reading level data so that appropriate subjects could be located. The most recent audiogram in the school records was used to categorize the degree of hearing loss. The unaided pure-tone thresholds for 500, 1000, and 2000 Hz for the better ear were averaged using the modification recommended by Graham (1960). That is, if a difference of 20 dB or more was found among the three threshold values, then the highest score (i.e., the poorest threshold value) was discarded and the pure-tone average (PTA) was based on the remaining two thresholds. Unaided scores were used rather than aided since the hypothesized differences in cognitive functioning were presumably laid down early in life prior to the use of a hearing aid. Furthermore, wearing of an aid is no assurance that it is properly set to provide

optimal correction (Gaeth & Lounsbury, 1966).

The hearing of all the hearing-loss children was screened again at the time of testing, using the portable Beltone audiometer. If there was a discrepancy between the PTA based on this testing and that obtained from the records, the source of error was sought. If this discrepancy could not be resolved (rarely), the school records were used as the final categorizing criterion since that examination was done under more rigorous conditions.

Normal-hearing grade 4 children were not screened for hearing losses. It was assumed that their hearing was normal since they were working up to grade level. Furthermore, hearing is screened at intervals in all of the school systems used; a hearing loss would have been detected previously in all probability if the child had remained in the system for any period of time. In addition, it was felt that children with very mild hearing losses could serve as a check on the assumptions made for the normal-hearing group. Losses of 0-25 dB are frequently termed nonsignificant with favorable placement in the classroom being the only treatment prescribed for such children. All hearing-loss subjects, including these, were treated alike in this project. Hearing was screened and the reading-vocabulary levels were used for selection. Many 0-25 dB children were indeed found in normal grade 4 classrooms. Thus, their performance and performance of normal-hearing children might be expected to parallel one another. To the extent that they do, they function as a check on the assumptions concerning normal-hearing subjects. Gross discrepancies in performance between the two groups would require careful consideration before attributing any significance to them other than merely representing differences in sampling.

Pure-tone thresholds were used to classify subjects in spite of the fact that the dimension which was being investigated is more closely related to speech. The task of identifying speech accurately is a complex problem dependent upon many factors. It might be thought of as occurring in two stages; reception and perception of speech. The former involves the peripheral auditory mechanism while the latter involves refined discrimination and differentiation (Hardy, 1965). Basic to the research was the assumption that the degree of implicit verbalness which characterizes an individual's thinking processes is directly related to the amount of speech which he has the potential to receive. Thus, the concern was primarily with the threshold for speech reception. Clinically, this is defined as the intensity at which 50% of a list of spondaic words are recognized. It has been shown, however, that the averaged thresholds for certain pure tones provide a good estimate of the speech

reception threshold (Fletcher, 1929; Harris, 1965). Therefore, PTAs were used to select and classify hearing-impaired subjects. Hearing loss is expressed in decibels (dB) relative to audiometric zero (normal hearing level) using ISO 1964 norms throughout this study.

Speech discrimination scores were not used for selection. That task is more difficult and assesses both speech perception and speech reception. No simple relationship exists between speech discrimination scores and either the speech reception threshold or pure-tone thresholds. Discrimination ability is frequently nil, using traditional clinical procedures, with subjects who have severe hearing losses while pure-tone thresholds can still be determined. Thus, selection on the basis of speech discrimination would have eliminated most if not all of the more severely impaired children from this study.

Reading ability was used as a selection criterion rather than grade placement for subjects with hearing losses. With normal-hearing children reading level generally corresponds quite well to grade placement. However, with language handicapped children grade placement is determined by a number of factors with the result that reading level may be somewhat lower than grade level. For the purposes of this study, reading level was a more valid measure for equating or comparing groups differing in hearing ability. The most recent school records provided this information. All children scored from 3.5 to 6, inclusive, on this measure.

Children with problems other than impaired hearing were generally eliminated from the sample. In particular, no child classified as retarded, or having severely impaired vision even when corrected, or with gross motor problems, or who was classified as having severe emotional disorders was used. Thus, the samples used were drawn from a population whose primary handicap is impaired hearing; in most other respects this population might be considered normal or at least representing a range of behavior which is similar to that seen in normal-hearing subjects.

Since hearing ability is critical to the development of language, only children whose losses predate the age of onset of speech (24 months) were used. Acquisition of language skills in these children proceeds more slowly; therefore, imposing specific reading level requirements increased the chronological age of the hearing-impaired subjects as compared with the normal-hearing subjects. The amount of the age difference increased with increased hearing loss.

These, then, were the general requirements for inclusion of a hearing-impaired child in this study:

(a) a sensorineural hearing loss for the speech frequencies,

(b) the onset of the loss predating the age for acquisition of speech,

(c) reading level no lower than 3.5 nor higher than grade 6, and

(d) average intelligence with no other gross physical or behavioral disabilities.

Initially, it had been planned to use hearing loss categories as described by Davis (1965) and reproduced in Table .1. However, the categories finally used had to be broadened to raise sample sizes to adequate levels. Realignment of categories attempted to maintain the general broad hearing-loss categories of mild, hard-of-hearing, and deaf to facilitate the comparison of the performance of these groups (Silverman, 1966; Streng, 1960). The specific categories used will be described in the Method sections for each of the three experiments.

Procedures

Two basic procedures were used in this project: group testing and individual testing. Group testing was used in the standardization of the lists designed for Experiment 1 and also was used in collecting normal-hearing data for Experiment 2. Individual testing was employed for Experiment 1, with all hearing-loss subjects in Experiment 2 and exclusively for Experiment 3.

Group testing. In general, group testing was conducted as follows: Intact classrooms of grade 4 subjects were used. The teacher had the option of remaining in the room or not as she (he) desired. Two experimenters were used. While one set up the equipment and served as monitor, the other distributed response booklets and explained the task to the class. The children were instructed to place certain personal information on the cover of the response booklet (name, school, date, age, sex, grade, and a code identifying the experimental condition assigned to that class). Following this, the task was presented visually in a series of alternating study and test trials. During study trials, the children were instructed to attempt to learn the responses which accompanied the stimuli. Each stimulus word was projected on the screen for 2.0 seconds followed by its response word for another 2.0 seconds. A blank frame was projected for the interpair interval of 2.0 seconds. During test trials, the subjects were instructed to write down the

TABLE .1

Classes of Hearing Handicap, From Davis (1965)
ISO--1964

dB	Class	Degree of Handicap	Average Hearing Threshold Level For 500, 1000 and 2000 in the Better Ear: More Than	Average Hearing Threshold Level For 500, 1000 and 2000 in the Better Ear: Not More Than	Ability to Understand Speech
	A	Not significant		25 dB (ISO)	No significant difficulty with faint speech
25					
	B	Slight Handicap	25 dB (ISO)	40 dB	Difficulty only with faint speech
40					
	C	Mild Handicap	40 dB	55 dB	Frequent difficulty with normal speech
55					
	D	Marked Handicap	55 dB	70 dB	Frequent difficulty with loud speech
70					
	E	Severe Handicap	70 dB	90 dB	Can understand only shouted or amplified speech
90					
	F	Extreme Handicap	90 dB		Usually cannot understand even amplified speech

correct response word if they recalled it upon viewing each of the stimuli. They were encouraged to guess. Each stimulus word was projected for 2.0 seconds followed by an inter-item interval of 6.0 seconds to allow sufficient time for writing down the response. Intertrial intervals were 20.0 seconds. All of these timings were controlled by tone bursts recorded on magnetic tape, inaudible to the class.

A total of 10 sets of alternating study-test trials was used in the standardization of Experiment 1 lists while 12 sets were used in the group testing for Experiment 2. The criterion score in both cases was the total number of correct responses for the fixed number of trials. Three different random orders of the stimulus-response pairings were used for study trials and another three orders of stimuli were used for the test trials.

Individual testing. Procedures for individual testing varied depending on the experiment to which the subject was assigned. In general, testing was conducted in an unused room provided by the school. The room was reasonably quiet, isolated, and large enough to accommodate a child's desk, the projector, a screen, a table for the equipment, and chairs for the two experimenters. One experimenter operated the equipment while the other instructed and supervised the child. Audiometric screening preceded the experimentation in all individual testing.

For Experiment 1, repeated measures were used which required each child to be tested at four separate sessions. During the first session, he received the practice list followed by one of the experimental lists. The two lists were administered in the same response modality (oral or written) as determined by the first experimental list. All presentations were visual. The order in which lists and response modalities were administered was counterbalanced; each subject was randomly assigned to an order at the first session. The remaining three lists for Experiment 1 were administered in separate sessions with at least one hour elapsing between successive sessions; more usually, a half-day separated the two sessions. The number of trials needed to reach one errorless trial was the criterion score for Experiment 1. The timing and sequencing of the materials for the written response conditions were the same as given for group testing. Oral response conditions had a shorter interitem interval in test trials, 4.0 seconds instead of 6.0 seconds, since it takes less time to speak a response than to write it. All other temporal parameters were the same.

Individual testing for Experiment 2 also used the practice list. Following this, the experimental list was administered for 12 sets of trials, alternating study and test

trials. Each child received only one of the experimental lists. Visual presentation and written responses were used throughout Experiment 2. The timing was as described for group testing.

A fairly rigid scoring criterion was used in Experiments 1 and 2. The responses had to be completely correct in spelling or pronunciation before they were scored right. Language of hearing-impaired children is distorted and extra precautions were taken to allow for this. One of the experimenters was a speech therapist who had had previous experience with speech of the hearing-handicapped. During the audiometric screening and the instruction phases of the session, the experimenter familiarized herself with the speech patterns of the child. She also used facial cues for phonemic identification as the child spoke. Knowledge of results was not provided any of the subjects either during or after participating in the study. However, general reinforcement in the form of encouragement was applied throughout the sessions.

For Experiment 3, individual testing was conducted in the same physical setting. However, practice with interpolated activity (counting) and with five sets of triads preceded the task. Presentation was again visual and responses were oral. The experimenter tried to identify responses of the subjects by using the techniques described above with severely impaired subjects and by repeating the words to be sure they were what the child intended. Details of presentation parameters will be given later. The experimenter continued until valid data for a total of 60 triads had been obtained.

These, then, were the general procedures used in the project. The cassette tape recorders were used to record all oral-responding conditions. More detailed descriptions of the specific procedures used for each experiment will be presented later. No single testing session in any of the experiments exceeded 40 minutes.

CHAPTER III

RESULTS

Since the data for this project have been collected as three separate experiments involving different materials, subjects, and/or procedures, the presentation of results will maintain this same structure. Each experiment will be reported and discussed separately in detail. The next chapter will attempt to bring these findings together and arrive at conclusions based on the three experiments.

Experiment 1 was designed to verify and extend the findings reported by McLinden (1959). As already mentioned, she found that six groups of children with different degrees of hearing impairment learned a list of "visual" rhymes more rapidly than "auditory" rhymes while two groups of children with normal hearing performed in just the opposite manner. The implications of these results were such that further study of the differential performance of normal and hearing-loss subjects was indicated. Therefore, Experiment 1 undertook to reassess these findings and to explore the interaction between modality of rhyming dimension and modality of response.

Experiment 2 explored the hypothesis of qualitative differences in the cognitive processes of hearing and hearing-loss subjects by measuring the relative effects of interference with learning. Following Dallett's (1966) example, lists of word-pairs were constructed in such a manner that interference would result if the materials were learned in an implicit acoustic fashion. This task was assumed to be more difficult than the straightforward utilization of cues for learning provided in Experiment 1; it provided another independent test of the major hypothesis concerning qualitative differences.

Experiment 3 assessed the relative efficiency of short-term memory for verbal material in children with normal and with impaired hearing. This study was designed to evaluate the functional equivalence of the storage and retrieval processes of the various groups of children participating in the experiment, regardless of the thinking process they might be using.

Experiment 1

Imagery, Response Mode, and Hearing Ability

Children with impaired hearing present a definite educational problem. The effect of early severe hearing impairment is seen primarily in later retarded language skills. In general, the more severe the hearing loss, the greater the language deficiencies. Furth (1966) stated the problem well when he said "The fact is that under our present educational system the vast majority of persons born deaf do not acquire functional language, even after undergoing many years of intensive training." (page 13, italics his). Children with hearing losses of lesser magnitude also demonstrate reduced verbal skills. Even the mild hearing loss results in at least a year's retardation in school achievement (Goetzinger, 1962; Goetzinger et al., 1964).

The most usual interpretation of these facts is to assume that loss in hearing ability interferes with the development of language quantitatively. That is, the language of the hearing-impaired is regarded as representing some less well developed, immature stage of verbal functioning through which all persons pass. This assumption has encouraged educators to expose the language-deficient child to more intensive drill and other steps designed to accelerate his verbal development.

In contrast to this quantitative view of language development, it is suggested that the hearing-impaired are language-deficient because they develop in a qualitatively different fashion. As already discussed in Chapter I, the early hearing loss may alter the perception of the world so that the child places primary emphasis upon sense modalities other than hearing. The dimensions underlying cognitive processes would then be formed along visual-tactile lines rather than auditory-visual or whatever best describes the normal-hearing process.

Evidence for a qualitative difference between normal and impaired-hearing performance is sparse since this thesis has not been formally advanced previously. However, Conrad and Rush (1965) concluded that deaf and normals differ in the manner in which they stored items in short-term memory. Similarly, Odom and Blanton (1967) found that the deaf processed word phrases differently from normal-hearing subjects. Other studies (Blanton & Nunnally, 1967; Blanton & Odom, 1968) showed that pronunciability influences normal-hearing subjects but not the deaf. The dimensions underlying deaf performance have not been identified, however.

It was hypothesized here that the visual-tactile organization of the deaf child's mind predisposes him to view the world differently and, more important educationally, to view verbal material differently. The hearing child probably transforms written verbal material to its auditory equivalents as suggested by the numerous studies of coding and memory. This is natural for him since oral language precedes his learning of the written mode. The hearing-handicapped child may not make these same transformations since oral language is not "basic" to him. It is this difference which is suggested as the foundation for qualitatively different strategies.

One way to approach the issue of qualitative differences is to use the concept of imagery in thinking. If auditory memory has been demonstrated satisfactorily in normal-hearing subjects, then similar tasks can assess the use of "nonauditory" memory. The unpublished research of McLinden (1959), mentioned so frequently in this report, was really the pilot study for this experiment, although it was not so planned initially. Her basic procedure was to provide direct auditory or visual cues for learning a paired-associate task. It has been shown that stimulus-response similarity facilitates acquisition when it is within pairs (Thompson & Fritzler, 1967). The use of two kinds of cues allows qualitative differences in approach to printed verbal materials to be measured, whereas employing only one kind of cue would indicate merely that one group used that cue to better advantage than did another group.

The term "imagery" is used to refer to the internal process evoked by the stimulus materials. Printed words can be retained either on the basis of their sounds or their spelling as a first-order process; higher order processing would use meaningfulness for retention. The easiest way is most favored as embodied in the "principle of least effort" (Zipf, 1949). Thus, if word pairs are presented for learning with an obvious cue provided, the cue will be used to the extent that it facilitates the learning process.

McLinden found printed word pairs which sounded alike were easier for normal-hearing subjects while printed word pairs which looked alike were easier for hearing-loss subjects. For convenience it might be stated that auditory imagery is used by the hearing subjects and visual imagery by those with impaired hearing. However, all of her subjects responded orally. This response mode might have influenced the pattern of the normal-hearing children more so than the impaired groups since, admittedly, the child with all normal sensory faculties has more flexibility to his behavior. Thus, speaking the answers might have favored the use of auditory imagery since the information was then

stored in the form needed for responding. However, such alteration of retention modality is not consistent with the thesis that auditory imagery is employed because of its efficiency for processing information. Thus, different results were not expected in the patterning of performance if written responses were used.

The purpose of this experiment, then, was to compare the performance of normal-hearing and hearing-impaired subjects in paired-associate learning using visual and auditory imagery, and to examine the interaction between such imagery and response mode in the different hearing categories. It was hypothesized that

(a) the hearing-handicapped children would excel with visual imagery while normal-hearing children would perform better with auditory imagery, and

(b) no interaction was expected between imagery and response mode in any of the groups.

Method

Materials. The materials used in this experiment have been described previously (Chapter II). Briefly, they consist of two lists of eight word-pairs which rhyme but are spelled differently (designated auditory lists) and two lists of eight word-pairs which are spelled similarly but differ in pronunciation (visual lists). The complete lists are presented in Appendix C. Prior to using these lists, standardization of the materials was conducted to determine their relative difficulty. These data are described in Appendix A. The results showed that the two auditory lists were more difficult than the visual, at least under group testing procedures and using written responses.

Subjects. A total of 45 children was tested for Experiment I. Table 1.1 summarizes the groups in terms of age, sex, hearing ability, and reading-vocabulary grade equivalent. The hearing-loss categories might be labeled mild, moderate or hard-of-hearing, severe, and profound or deaf. PTAs for normals were not obtained; this value is assumed to be zero as discussed in Chapter II.

Procedure. A detailed description of the procedure for individual testing has already been given. One each of the auditory and visual lists was assigned to a written response condition, the others being oral. The list-response combination changed for each child. Thus, four experimental conditions were formed: oral auditory (OA), oral visual (OV), written auditory (WA), and written visual (WV). Order of

TABLE 1.1

Summary of the Five Hearing Categories From Experiment 1 in Terms of Age, Sex, Hearing Level, and Reading Level

Group	N	Age	Sex		PTA	RL
			M	F		
Normal	13	9.19	7	6	-	3.71
0-25	7	11.14	4	3	8.28	4.10
26-65	8	13.25	5	3	47.87	4.66
66-90	8	13.62	3	5	79.50	4.46
91+	9	14.22	2	7	103.00	4.43

administration of the four lists was counterbalanced and each subject was assigned to an order at the first session. Audiometric examination was done for all but the 13 grade 4 children.

The practice list of unrelated words was administered in the same response modality as the first test list; e.g., if the first test condition was to use written responses, practice was also written. Practice continued until the subject understood the task. Usually only a few trials were needed. This was followed by the first test list; alternate study and test trials were administered until the child achieved one errorless trial. Booklets were used for written response conditions; a cassette tape recorder was used for oral responding. Simultaneously, during the oral response conditions the experimenter kept a written record of the child's progress in order to be able to verify criterion in the event that the tape recording was faulty. However, errors were only scored, not described, so that error analyses were not possible with only the experimenter's scoring sheets. In written conditions, the experimenter examined responses to the preceding test trial during the next study trial or else monitored them as the child wrote; the results were not communicated to the subject. The remaining three lists were administered similarly at separate sessions.

At no time was the child's attention directed toward the relevant dimensions for the cues; each session was begun with a statement to the effect that a set of word pairs was to be learned and the response mode was defined. In general, the first session lasted 40 minutes with succeeding sessions being much shorter. The final session frequently was completed

within 10 minutes total time.

Results

The first concern in this experiment was whether the practice list had been effective in bringing all subjects to the same level of task comprehension, or whether there was a trend toward increased proficiency in learning the lists with each succeeding session. An examination of the mean trials to criterion for the various groups of subjects for sessions 1, 2, 3, and 4, ignoring lists and modality of response, revealed no orderly effects as a function of sessions themselves. These data are summarized in Table 1.2. It was concluded that the practice list had been effective in eliminating any learning-to-learn phenomenon.

TABLE 1.2

Mean Trials to Criterion by Sessions for Five Categories of Hearing Ability

Hearing Ability	Session 1	2	3	4
Normal	5.15	5.46	3.69	4.85
0-25	6.29	5.57	5.86	5.71
26-60	6.00	5.13	5.13	4.50
61-90	4.50	4.75	4.75	4.50
91+	4.67	5.22	5.11	5.11

Trials to Criterion. The mean number of trials to a criterion of one errorless trial for the various hearing categories by experimental condition is presented in Table 1.3. These data are also graphically presented in Figure 1.1. Standardization of the lists using grade 4 classes, group testing, and written responses had shown that the auditory lists were more difficult than the visual (Appendix A). The same pattern is obtained in all groups except the normals in this experiment. One other point that deserves mention is the somewhat greater variance exhibited by the 0-25 dB group for the two auditory lists as compared with all other variances.

The data from Table 1.3 were analyzed first using the procedure for three factors (hearing ability, modality of cues, and modality of responses) with repeated measurements

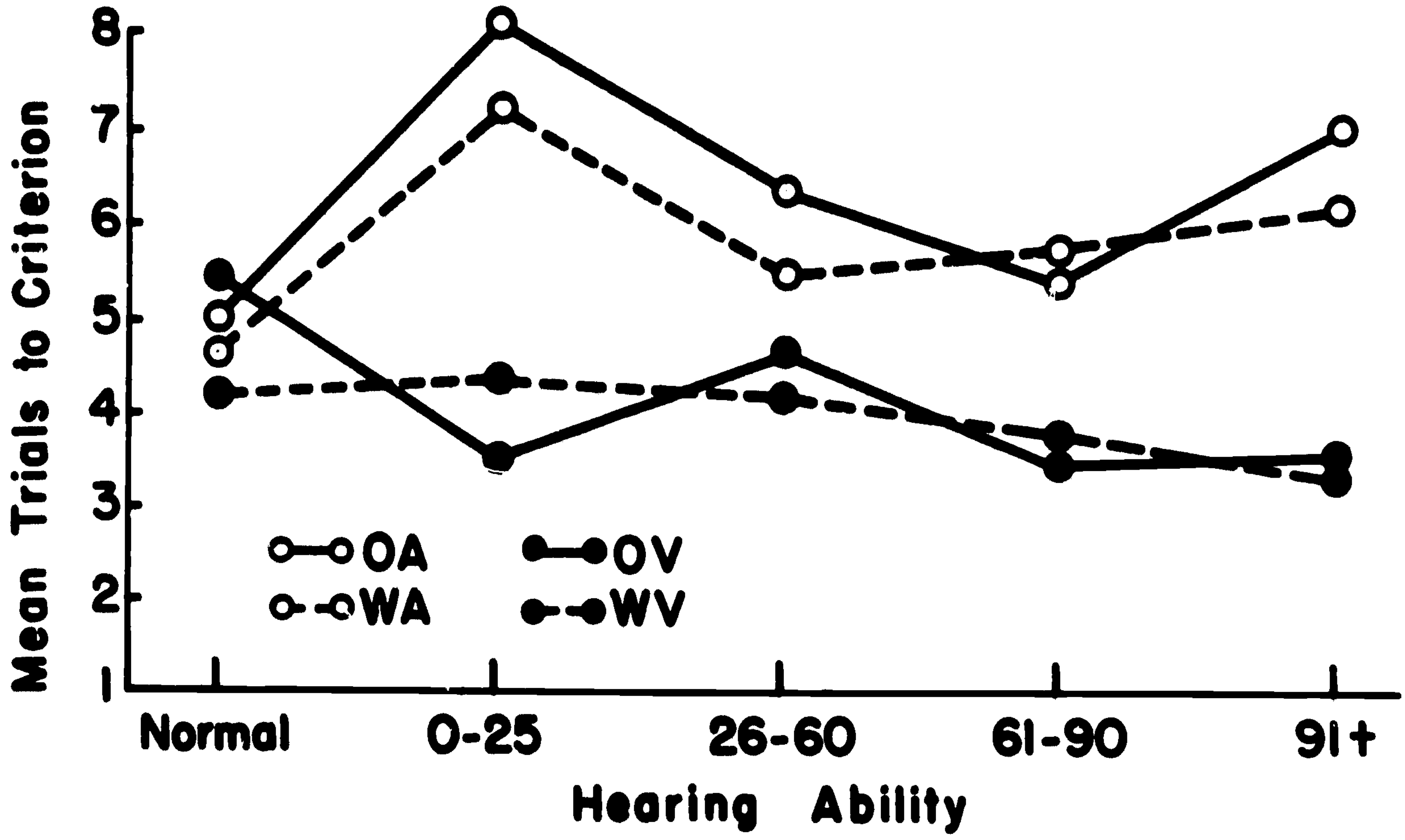

Fig. 1.1. Mean trials to criterion in four conditions for five hearing categories.

TABLE 1.3

Mean Trials to Criterion (TTC) and Standard Deviations (SD) in Four Experimental Conditions for Five Hearing Categories

Hearing Category	N		Condition OA	OV	WA	WV
Normal	13	TTC	4.77	4.92	4.69	4.15
		SD	1.74	2.84	1.97	1.68
0-25	7	TTC	8.14	3.57	7.29	4.43
		SD	3.02	1.14	4.82	1.27
26-60	8	TTC	6.38	4.75	5.50	4.13
		SD	2.93	2.25	2.33	2.17
61-90	8	TTC	5.50	3.63	5.63	3.75
		SD	1.31	1.30	3.11	1.49
91+	9	TTC	7.00	3.56	6.11	3.44
		SD	2.55	1.60	1.69	1.60

on the last two factors (Winer, 1962). The summary table for the analysis of variance, Table 1.4, shows that cues

TABLE 1.4

Summary of Analysis of Variance of Five Categories of Hearing Ability for Two Kinds of Cues and Two Kinds of Responses

Source	df	MS	F
Between Ss	44	8.96	
Hearing Ability (H)	4	8.28	.92
Ss w. groups	40	9.04	
Within Ss	135	5.16	
Cues (C)	1	153.09	28.40**
HxC	4	18.52	3.44*
CxSs w. groups	40	5.39	
Responses (R)	1	5.00	1.57
HxR	4	1.05	.33
RxSs w. groups	40	3.18	
CxR	1	.93	.34
HxCxR	4	1.87	.67
CxRxSs w. groups	40	2.77	
Total	179		

*$p < .05$
**$p < .01$

and the interaction of hearing category with cues were the only significant sources of variance. Post-mortem examination of the main effect due to cues showed that the two visual lists required significantly fewer trials to criterion than did the two auditory lists, consistent with the results of the standardization data. The significant interaction between hearing and cues was due primarily to the significantly poorer performance of the 0-25 dB group as compared with normals on the auditory list. None of the differences among groups for the visual lists was significant. Between cues for a particular hearing group, those with 0-25 dB and with 91+ dB hearing losses performed significantly better

with the visual cues than with the auditory. The Scheffé procedure was used for these _a posteriori_ comparisons; its conservatism has been commented on by Winer (1962). All comparisons are at the .05 level of significance.

The data for each hearing category were also analyzed separately to evaluate the roles of modality of cues and modality of responses. Essentially the same results were obtained as from the preceding analysis, the only difference being for the group with 61-90 dB hearing loss which was now found to be significant as a function of modality of cues. For the 13 normal-hearing grade 4 subjects and for those with 26-60 dB losses, no significant sources of variance were obtained. For groups 0-25, 61-90, and 91+ dB hearing losses, the modality of cues was significant. In all three groups the visual lists were significantly easier (requiring fewer trials to criterion) than the auditory lists. Table 1.5 presents the summaries for all five of the analyses. In no group was the interaction between cue and response modalities significant, nor did this interaction approach significance in the previous analysis.

Learning curves for the various hearing groups for the four conditions were constructed and are presented in Figures 1.2, 1.3, 1.4, and 1.5. The points represent mean trials needed to learn the first word pair (regardless of which one it was), the second pair, etc. The cassette tape for one subject in the 26-60 dB group was defective so that data for learning curves were not available for him. The two auditory conditions (WA and OA, Figures 1.2 and 1.3, respectively) both show a marked spread among the five hearing ability groups while the visual conditions (WV and OV, Figures 1.4 and 1.5, respectively) show much greater consistency in the rate of acquisition of the word pairs regardless of hearing loss. Since repeated measures were used, the differences can be attributed to materials and not to sampling differences. Also the order of presentation of the lists was counterbalanced to offset any bias due to sequencing effects. The overall poorest performance on the auditory lists was obtained from the 0-25 group; this is in contrast with their performance on the visual conditions where they were well within the limits set by the other groups. It must also be noted that the normal-hearing group learned the auditory lists fastest of any of the groups but were the slowest or nearly so on the visual lists. Similarly, the 91+ dB group lies generally next to the top (poorer performance) on the auditory and at the bottom (faster learning) on the visual lists.

Pearson product-moment correlations were obtained between age and performance and between PTA and performance for all the hearing-loss subjects (i.e., including all

TABLE 1.5

Summaries of Analyses of Variance of Modality of Cues and Modality of Responses for Each Hearing Category

Source	Hearing Category														
	Normal			0-25			26-60			61-90			91+		
	df	MS	F	df	MS	F	df	MS	F	df	MS	F	df	MS	F
Cues (C)	1	.48	.10	1	96.57	9.75*	1	18.00	3.00	1	28.12	6.08*	1	84.05	30.98**
Responses (R)	1	2.33	.58	1	0	0	1	4.50	1.91	1	.12	.04	1	2.27	.89
Subjects (S)	12	7.44		6	14.07		7	13.27		7	4.57		8	7.84	
CxR	1	1.56	1.12	1	5.14	.79	1	.12	.06	1	0	0	1	1.34	1.03
CxS	12	4.98		6	9.91		7	6.00		7	4.62		8	2.71	
RxS	12	3.99		6	4.83		7	2.36		7	3.34		8	2.56	
CxRxS	12	1.39		6	6.48		7	2.12		7	2.79		8	1.30	
Total	51			27			31			31			35		

$*p < .05$
$**p < .01$

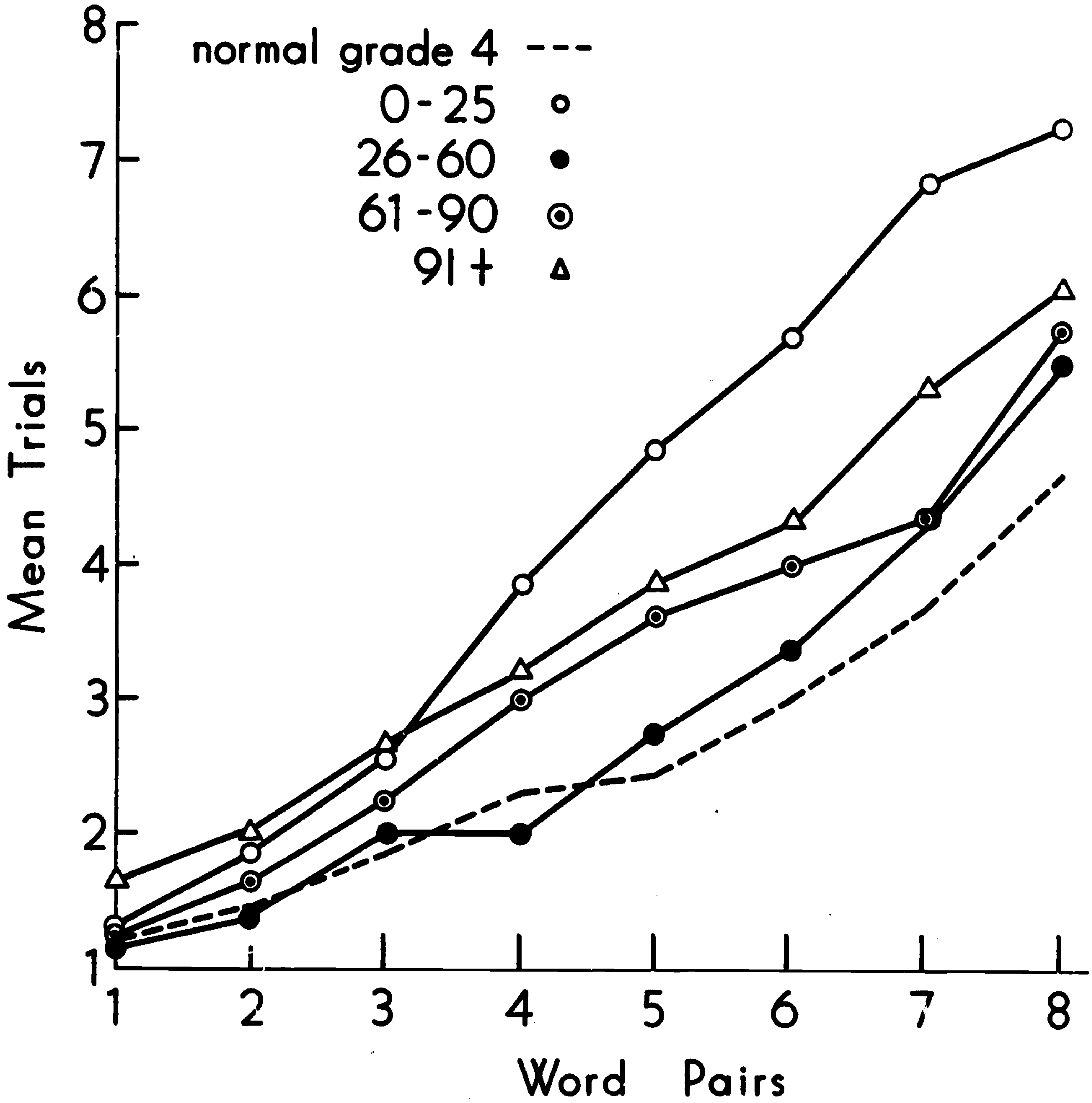

Fig. 1.2. Learning curves for five categories of hearing ability in written auditory condition.

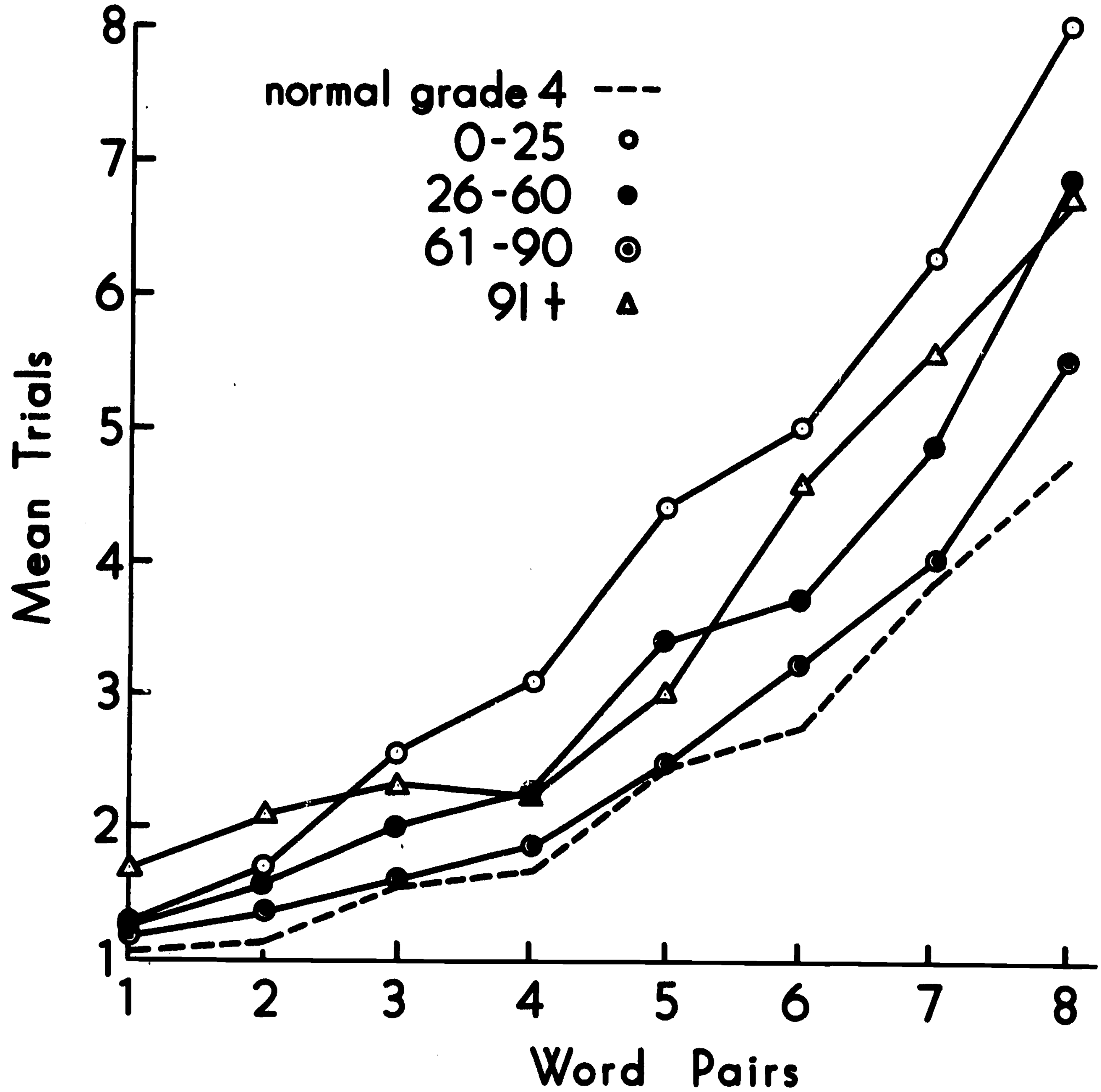

Fig. 1.3. Learning curves for five categories of hearing ability in oral auditory condition.

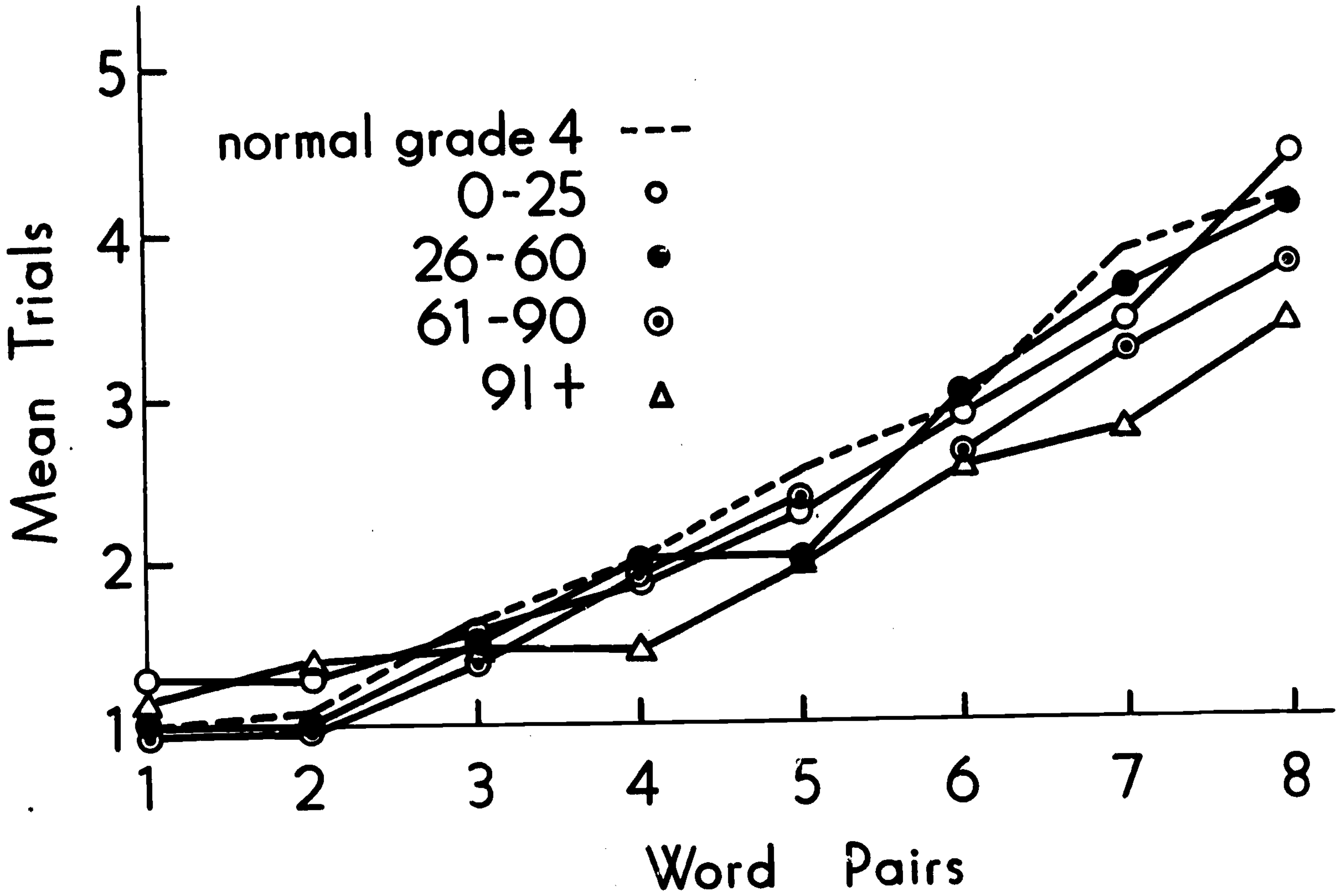

Fig. 1.4. Learning curves for five categories of hearing ability in written visual condition.

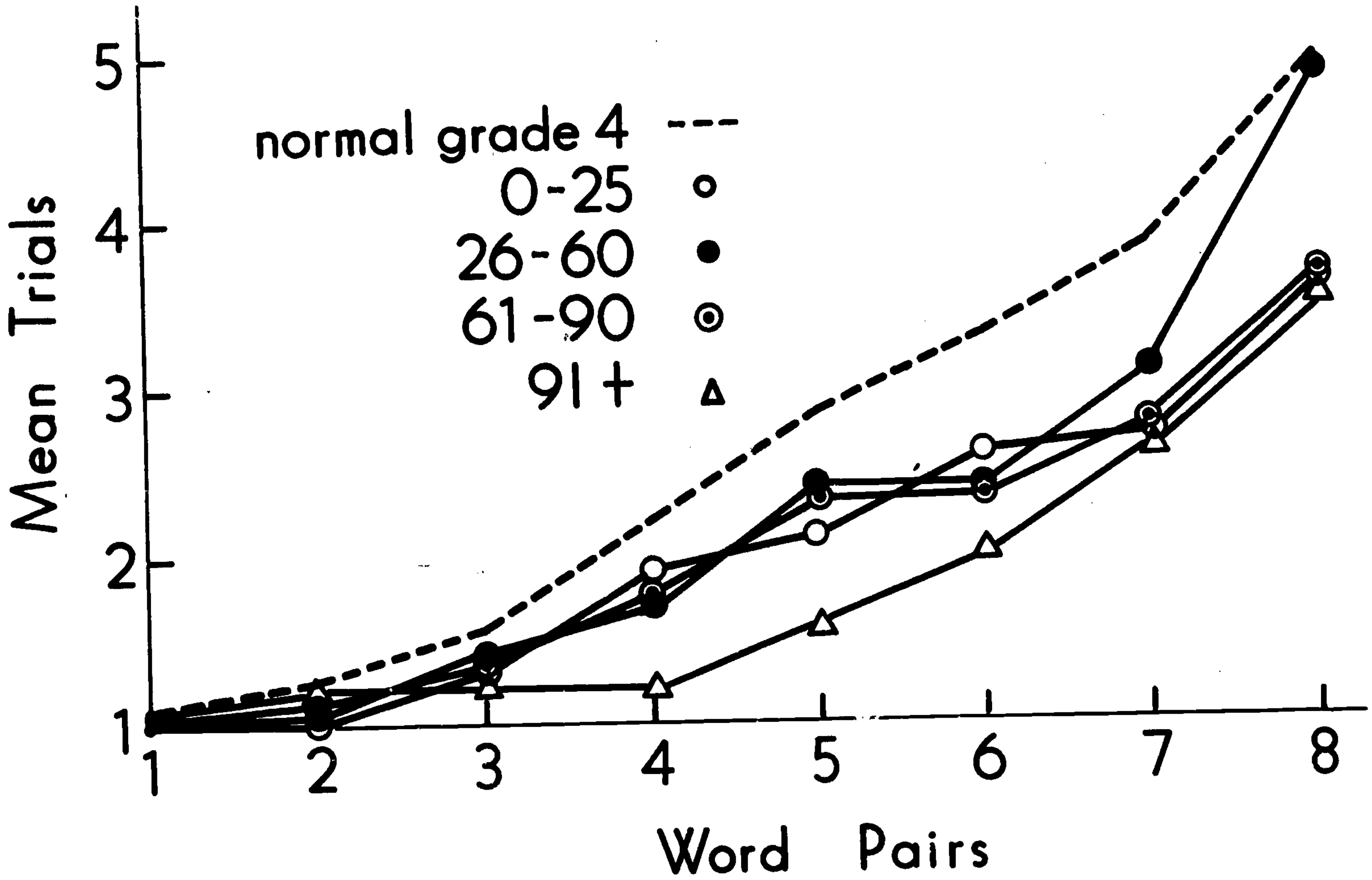

Fig. 1.5. Learning curves for five categories of hearing ability in oral visual condition.

categories except normal) for the four experimental conditions. They ranged in magnitude from .03 to -.12 for age and performance and from -.08 to -.23 for PTA and performance. None of the correlations was significantly different from zero at the 5% level, a critical value of ± .296 being required.

Errors. Error analyses were done for all the conditions and hearing category combinations. Twelve error categories were defined and all errors were assigned to one of these classes. One category of omissions was used; three categories of intralist intrusions (another response word, the same stimulus word, or another stimulus word), and eight categories of extralist intrusions (word rhyming with the stimulus, with the response; word spelled like the stimulus, like the response; a word conceptually related to the stimulus, to the response; a word not obviously related to either stimulus or response; and misspelling or mispronunciation errors). Only 11 categories were used with any one condition since a rhyming extralist intrusion in an auditory list would rhyme with both the stimulus and response words and a visually similar extralist intrusion in a visual list would be spelled like both the stimulus and response words. Table 1.6 summarizes the proportions of errors classified as omissions, intralist intrusions, and extralist intrusions for each hearing group under the four experimental conditions.

TABLE 1.6

Proportion of Different Classes of Response Errors for Five Hearing Categories and Four Conditions

Error Class	Condition	Normal	0-25	26-60	61-90	91+
Omissions	OA	.81	.84	.65	.85	.83
	WA	.76	.70	.59	.70	.76
	OV	.74	.92	.72	.78	.73
	WV	.85	.67	.80	.72	.75
Intralist Intrusions	OA	.06	.13	.16	.10	.14
	WA	.12	.03	.13	.06	.14
	OV	.10	.07	.02	.10	.17
	WV	.07	.09	.01	.15	.16
Extralist Intrusions	OA	.12	.03	.18	.05	.02
	WA	.11	.27	.28	.24	.10
	OV	.17	.00	.25	.12	.09
	WV	.09	.24	.19	.12	.09

As shown there, by far the largest proportion of errors was omissions. These ranged from 59% of all errors for group 26-60 dB in condition WA to 92% for group 0-25 dB in condition OV. Thus, approximately two-thirds or more of the wrong responses were no responses. It had been hoped that extralist intrusions might differentiate among the groups and provide further insight into the process by which the materials were being learned. However, so few useful errors of this kind were made by any of the groups that this line of investigation proved fruitless. The most frequent kind of extralist intrusions shown by all groups was misspellings or mispronunciations.

Discussion

The two hypotheses tested in this experiment were (a) that hearing-handicapped children would excel with visual imagery while normal-hearing children would perform better with auditory imagery and (b) that no interaction was expected between imagery and response mode in any of the groups. The data are suggestive but not clear-cut supporting the first hypothesis; evidence for the second hypothesis is more certain in failing to reject the null position. As indicated in Tables 1.4 and 1.5, there is no trend toward a modality-of-cue by modality-of-response interaction in any of the groups tested.

Returning to the first prediction, a significant modality-of-cues by hearing category interaction was obtained when all groups are considered and was seen also in the 0-25, 61-90, and 91+ dB hearing-loss groups when separate analyses of each group were conducted. Furthermore, in all three groups, the difference was in the predicted direction, the visual material being learned more rapidly than the auditory. These data are supportive of the results obtained by McLinden (1959) who also found a significant interaction between hearing ability and modality-of-cues.

The fact that standardization of the lists had shown that the auditory lists were more difficult than the visual appears to be a procedural artifact since the normal-hearing subjects in this experiment did not differ significantly in performance on the two kinds of material. The difference between the lists is about eight correct responses, i.e., about one correct trial. Thus, the trials-to-criterion procedure would be less sensitive to this difference. Conversely, if one accepts the validity of the standardization findings and applies them to this study, then one might conclude that list difficulty operated against the role of cues and the "true" results would be in favor of the superiority of auditory cues for normal-hearing subjects.

What would this reinterpretation do to the rest of the groups? Assuming that list difficulty is constant for all groups, the pattern shown in Table 1.7 would probably emerge.

TABLE 1.7

Differences Between Mean Trials-to-Criterion Scores for Auditory and Visual Materials for Five Hearing Categories

Group	A-V Differences	
	Obtained	Adjusted[a]
Normal	.19	-1.68
0-25	3.71	1.84
26-60	1.50	-.37
61-90	1.87	0
91+	3.06	1.19

[a]See text for adjustment procedure.

The data were generated by taking the mean difference in group 61-90 for the two kinds of cues and applying this correction factor to all groups. This difference of 1.87 was arbitrarily selected because it was the smallest mean difference to achieve significance. It is recognized that intragroup variance is a factor in significance and that the groups differed in this respect as shown by the mean square values for subjects across groups (Table 1.5). It is illustrated further by the fact that a mean difference of 3.06 for the group with 91+ dB hearing loss was significant beyond the .01 level while the numerically larger difference of 3.71 for group 0-25 was only significant at the .05 level. Applying the rather arbitrary correction factor to the auditory-visual differences which were obtained produced the adjusted differences shown in Table 1.7. Examination of either the obtained or the adjusted differences suggests that at least some of the hearing-loss groups would perform better on the visually similar lists than with the acoustically similar and none would show the reverse trend. The purpose of this exercise was primarily to offset any suspicion that the direction of obtained significances perhaps reflects merely the differences in list difficulty as demonstrated by the standardization data.

The results of this experiment reinforce the theory that a congenital hearing loss results in different

strategies being used in learning verbal material. The evidence is even more compelling since wide hearing-loss categories and small sample sizes were used. Since the cues for learning word pairs are constant within a list, it might be assumed that differences in performance reflect differences in the time needed to recognize the relevant dimension. Once the subject realizes that two words in a pair either sound alike or look alike, it should be relatively easy for him to apply this rule to the remaining pairs. Thus, it would be possible for the groups to differ in the interval of time (number of trials) needed to recognize the relationship and for learning to proceed at the same rate in all groups once such insight is obtained. In fact, this did not occur. The learning curves for the four experimental conditions show just the opposite trend. The groups did not show marked differences in terms of acquiring the first pair with rapid acceleration after that. In particular, the curves for the 0-25 dB hearing-loss group on OA and WA suggest a laborious trial-by-trial acquisition of materials similar to that one might expect with unrelated word pairs. Thus, the learning curve data serve to demonstrate the assumed qualitative differences in approach to verbal materials by hearing and hearing-impaired children.

Why does the 0-25 dB group show the most dramatic effect of modality of cue? In general, a hearing loss of this magnitude is regarded as nonsignificant. Such children are included in regular classrooms with a recommendation for favorable seating. It is assumed that the amount of hearing remaining is sufficient to allow them to be treated as if they had no loss. And yet, the data suggest that these children are least like normals.

The within-group variance for the 0-25 dB group was large, suggesting a large amount of individual differences in performance. However, the *F* ratio took this into consideration and still was significant for mean trials-to-criterion with the two kinds of cues. This suggests that the typical child in the 0-25 dB hearing category did not attend to the rhyming dimension of the auditory lists; he could not or would not use this cue to facilitate learning. Even the requirements of oral response failed to emphasize for him the rhyming nature of the word pairs in condition OA. In fact, he did more poorly on the auditory lists than did the typical child with a profound hearing loss (91+ dB category) who has little residual hearing to aid him in recognizing the acoustic similarity.

As a possible explanation, it is tentatively suggested that the 0-25 dB hearing loss group may be demonstrating the effects of any degree of hearing impairment without

corrective training. As suggested in Chapter I, perhaps any loss in auditory acuity directs cognitive awareness to other sensory modalities for information. Thus, a mild loss would change the child's orientation drastically, out of proportion to the magnitude of the hearing impairment. For children with more severe hearing losses, auditory training and special classes are instituted to develop full use of the remaining hearing skills. These procedures may serve to redirect his attention to the auditory modality as a meaningful source of information. Without such techniques it might be assumed that he would perform like the child with a mild loss, only more so. If these conjectures are correct, then auditory training or its equivalent should also be prescribed for the "nonsignificant" hearing-loss subject in order to channel his attention also to this modality.

Experiment 2

Acoustic Interference in Paired-Associate Learning as a Function of Hearing Ability

Another way of gaining insight into the cognitive processes involved in learning is to identify those factors which interfere with such learning. Interference can be introduced in the acquisition phase and its effect noted in a retarded rate of learning, or it can be introduced in such a manner that its effect is observed primarily during the retrieval process by reduced recall.

Many different procedures can result in interference but one of the most useful in verbal learning involves the dimension of similarity. Similarity can occur along different aspects of verbal material, generally falling into categories of formal, meaningful, or conceptual similarity (Underwood, Ekstrand, & Keppel, 1965). Children have been shown to respond to the effects of the different kinds of similarity in the same way as do adults. Gaeth and Allen (1966) showed that formal similarity exerted no greater effect upon the performance of children in grades 4-6 than would be predicted from adult behavior contrary to Keppel's hypothesis (1964). Heckelman and Spear (1967) found that "associative and orthographic relationships in these [language] habits are important . . . as early as the second grade . . ." in a study of free learning. Formal similarity is the particular kind of similarity manipulated in this project. Usually, when this term is applied to verbal material, it implies that the items have letters in common. In this project, the "visual" lists of Experiment 1 fit this description but the definition needed to be expanded to include phonemes in common for the "auditory" lists.

Similarity can produce either facilitation or interference depending upon how it is used; to confuse the issue even more, the two effects are probably always operating simultaneously as Postman (1963) suggests and we only measure the excess of one over the other. Facilitation effects of similarity were used in Experiment 1 where high stimulus-response similarity along either visual or acoustic lines presumably aided learning. In this experiment, one of the same dimensions, acoustic similarity, was used to gain just the opposite effect, interference. Gibson's classic paper (1942) describes the probable mechanism of such interference through generalization.

Dallett (1966) explored the relative effects of interference on both acquisition and retention. He introduced interference by manipulating acoustic similarity, using two lists and college students for subjects. He designed lists in which acoustic similarity occurred either between lists or within lists. He further arranged his materials to form either "consistent" or "not consistent" pairings, the designations referring to whether homophonous stimuli had rhyming responses (consistent pairings) or responses which did not rhyme (not consistent pairings). He reported the results of several experiments, one of which is of particular interest to this project. Using trials-to-criterion for his data, he found that within-list similarity produced significant interference as compared to a control list and that pairings which were not consistent produced significantly more interference with acquisition than did the consistent pairings. Thus, taking the control list as zero interference, consistent pairings introduced some increment in interference and inconsistent pairings produced even more.

Dallett's study formed the basis for the present experiment. His finding that acoustic similarity interferred with learning reinforces the hypothesis that normal-hearing subjects use implicit aural attributes of words as cues for learning. This fact could be used to gain evidence relevant to the basic thesis of this research, namely that of qualitative differences in thinking processes as a function of hearing ability. Simply stated, if hearing-handicapped subjects do not use the same acoustic cues, then the interference effect will not be obtained and their performance will exceed that of normal-hearing subjects.

New lists had to be constructed with words more appropriate for children. The two auditory lists from Experiment 1 were used and the items were arranged to create lists of both consistent and inconsistent pairings. It was expected that normal-hearing performance would be adversely affected by acoustic similarity on both the consistent and the inconsistent lists with greater effects seen with the latter, if Dallett's results can be generalized to children. No

control list was used so any interference in acquiring the consistent list by normal-hearing subjects is based on interference. If the hearing-impaired are not subject to interference from acoustic similarity, their performance on the two lists should differ from normals in the following fashion:

(a) normal-hearing subjects would perform more poorly on the inconsistent than on the consistent list while hearing handicapped subjects would show no difference as a function of pairings of words, and

(b) normal-hearing performance on either list would be poorer than hearing-impaired performance.

Thus, an interaction between hearing ability and pairings of words was predicted. Graphically, one might express the expected results as shown in Figure 2.1, where the axes indicate increasing hearing loss from normal to deaf and increasing interference. The lists are designated "C" and "I"

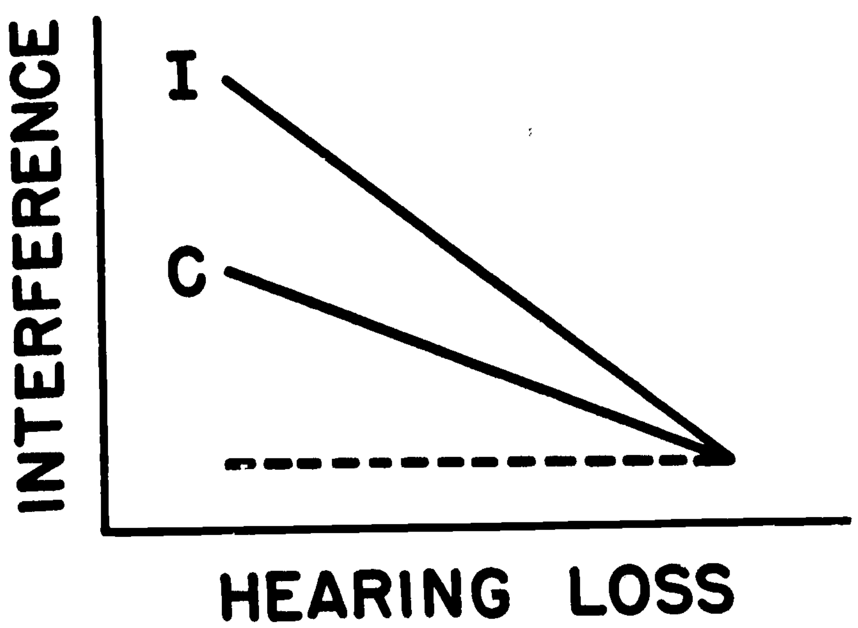

Fig. 2.1. Hypothesized interference as a function of pairings and hearing loss.

for consistent and inconsistent pairings, respectively. The expected value for a control list is shown as a dashed line and its slope is zero indicating no difference in amount of interference as a function of hearing ability.

These predictions are valid if one assumes that there are no interference or facilitation effects from dimensions other than acoustic similarity. Controls for this were introduced by using familiar words so that meaningfulness

would not exert a differential effect; associative strength between stimulus-response words was kept low (using intuitive criteria); the words differed in spelling although sounding alike to avoid confounding visual similarity with acoustic similarity.

Method

Materials. The two lists of rhyming words (auditory lists) used in Experiment 1 were also used in this experiment. Two new paired-associate lists were formed from each auditory list. The eight rhyming pairs of words in a list were arbitrarily divided into two equal sets, one set becoming stimuli and the other responses. New stimulus-response pairings were formed so as to be consistent in one list and inconsistent in the other, as defined by Dallett. For example, two rhyming pairs from an auditory list were taken (e.g., DOOR-MORE and SIGH-LIE); the first set was assigned to the stimulus category and the other became responses. In the consistent list, rhyming stimuli had rhyming responses (e.g., DOOR-SIGH, MORE-LIE) while, in the list with inconsistent pairings, the pairs were DOOR-SIGH and MORE-WHILE; the response LIE became paired with another stimulus. This procedure was followed for both auditory lists yielding two independent sets of inconsistent and consistent pairings. Each set of two lists (I-1, C-1 and I-2, C-2) contained exactly the same stimulus and response words; only the way in which they were paired was varied. All four lists were administered to separate classrooms of normal-hearing grade 4 subjects to determine whether the specific materials used constituted a significant source of variance. Only one set (I-1 and C-1) was used with hearing-handicapped children. The practice list of unrelated words from Experiment 1 was also used with the latter. The stimulus-response pairings for all four lists are presented in Appendix C.

Subjects. Twenty-one classes of grade 4 subjects were tested in this experiment using group testing procedures. Of these, six classes were discarded for being statistically deviant in performance. Each class learned a single list. Individual testing was conducted with 59 subjects assigned to hearing-loss categories, each subject learned only one list. Of 21 subjects in category 0-25 dB, 10 were assigned to list C-1 and 11 to list I-1. In category 26-65 dB hearing loss, six subjects learned C-1 and eight learned I-1. The category 66+ dB hearing loss had 24 subjects; half learned each list. None of the subjects had been used in Experiment 1. Table 2.1 summarizes the subjects tested individually in terms of age, sex, PTA, and reading-vocabulary grade level.

TABLE 2.1

Summary of Three Hearing Categories in Terms of Age, Sex, Hearing Level, and Reading Level for Two Conditions in Experiment 2

Group	C-1						I-1					
	N	Age	PTA	Sex M	Sex F	RL	N	Age	PTA	Sex M	Sex F	RL
0-25	10	10.5	5.3	6	4	4.3	11	13.2	8.6	4	7	4.5
26-65	6	11.5	48.0	3	3	3.8	8	11.6	47.5	8	0	4.0
66+	12	13.5	93.4	6	6	4.5	12	11.8	86.1	5	7	3.5

The hearing-loss categories differ from those used in the preceding experiment in that the severe and profound groups have been combined. Category boundaries were adjusted after the subjects had been obtained in order to maximize sample sizes while maintaining meaningful categories of mild, moderate, and severe hearing impairment. Data from an additional nine hearing-impaired subjects in category 0-25 were discarded since they had inadvertently been presented the consistent list from the second set of materials (list C-2). This precaution was taken although the means did not differ markedly (35.30 for C-1 vs. 33.89 for C-2).

Procedures. Group testing procedures were used with the classrooms of grade 4 subjects. A total of 12 alternating study and test trials were used. Visual presentation with written responses was employed as already described in the procedures section of Chapter II. Individual testing was conducted in the standard manner set forth previously. The list of unrelated word pairs was used for practice with these subjects. Other than that, the procedures were comparable to those used for group testing. All subjects who were tested individually were screened audiometrically prior to testing.

Results

Group testing. Table 2.2 summarizes the performance of 15 classes of grade 4 subjects on the two sets of inconsistent and consistent lists in this study (C-1, I-1 and C-2, I-2). More than two samples or classes per list were used because unidentified sources of variance among grade 4

TABLE 2.2

Summary of Group Performance on Two Sets of Consistent and Inconsistent Lists

	Set 1		Set 2	
	I-1	C-1	I-2	C-2
$\overline{X}$	35.29	37.22	36.78	31.50
SD	23.74	24.00	19.28	21.12
N	144	63	50	119

classes manifested themselves. Although the classes were sampled in the same objective manner, six classes had to be discarded entirely due to rejection of the hypothesis that the samples were drawn from the same population, using the t test. Mean scores for these classes ran as low as 7.47. The remaining data, from classes which were not eliminated, were supplemented with additional classes to insure a better estimate of the population parameters for the various lists. It should be mentioned that the variance in performance among classes was felt to be a function of the classes themselves and does not reflect some inherent instability in the materials presented or in the procedures used. The classes which demonstrated such marked diversity were all drawn from a single school system but from various schools within it. (See Appendix A, Standardization of Lists for Experiment 1, where this same phenomenon was again noted.)

Data from the four lists were analyzed using a 2x2 factorial design (Winer, 1962), with pairings as one factor and set of materials (words) the other. The results of the analysis appear in Table 2.3. As suggested by the closeness of the means for the four lists, none of the sources of variance was significant. Thus, group testing failed to show differences in performance as a function of consistent and inconsistent pairings, contrary to Dallett's results.

<u>Individual Testing</u>. The mean numbers of correct responses over 12 trials obtained through individual testing of subjects in the three hearing-loss groups are reported in Table 2.4. These subjects (categories 0 through 66+ dB) were the only ones tested individually. A small sample (N= 10) of normal grade 4 subjects was randomly selected from the group data for each of the two lists and these values were entered into the table as well, primarily to provide some index of normal-hearing performance. It must be remembered that these data were obtained under group testing

TABLE 2.3

Summary of Analysis of Two Sets of Materials and Two Kinds of Stimulus-Response Pairings With Grade 4 Subjects

Source	df	MS	F
Materials (M)	1	739.92	1.46
Pairings (P)	1	453.36	.89
MxP	1	693.07	1.36
Within	372	508.16	
Total	375		

TABLE 2.4

Mean Correct Responses and Standard Deviations on Lists I-1 and C-1 for Four Categories of Hearing Loss

List		Normal (group)	0-25	26-65	66+
	$\overline{X}$	43.10	48.54	52.62	42.08
I-1	SD	19.77	24.18	26.23	25.25
	N	10	11	8	12
	$\overline{X}$	34.60	35.30	55.17	60.92
C-1	SD	21.64	23.02	21.71	25.03
	N	10	10	6	12

conditions and without the use of a practice list, so the relative performances can be compared only with caution. Smaller samples were used in order to keep all the data at about the same level of precision. It is interesting to note that the means of these randomly selected samples exhibit a trend even more contrary to the pattern expected on the basis of Dallett's study than do the group testing results. This is merely considered sampling error; however, it may indicate that the normal grade 4 group data were somewhat skewed rather than being distributed normally. Frequency polygons were drawn for the four lists but it was difficult to abstract the shape of the parent population

from them with any certainty. (See Appendix B re normal data.)

A 2x3 factorial analysis of the hearing-loss data was performed, with two kinds of pairings (consistent and inconsistent) and three levels of hearing loss (0-25, 26-65, and 66+). As shown in Table 2.5, none of the sources of variance

TABLE 2.5

Summary of Analysis of Variance for Three Degrees of Hearing Impairment With Lists I-1 and C-1

Source	df	MS	F
Hearing Loss (HL)	2	708.50	1.18
List (L)	1	173.99	.29
HLxL	2	1447.65	2.42
Within	53	597.95	
Total	58		

was significant. The lack of significance is at least in part a function of the large within-group variance. The wide categories of hearing loss made necessary by the small sample sizes served to increase variance. Task difficulty was another factor operating to increase variance in this study.

Looking at the data as illustrated in Figure 2.2, the trend seems to be positive for C-1 and zero for I-1. However, the lack of significance for the list by hearing loss interaction ($p < .10$) did not support this trend. In order to see whether significance could be demonstrated in some other meaningful fashion, the data were re-examined. The difference between lists for each of the hearing-loss groups was evaluated using t tests; only the 66+ group showed a significant difference between lists, with C-1 higher than I-1; $t\ (22)=1.84$, $p < .05$. Examination of the differences between groups with the same kind of material showed that the 0-25 dB group performed significantly lower than the 66+ group on C-1; $t(20)=2.48$, $p < .05$. No other difference for either list was significant. Since the 0-25 dB group can be taken as "normal," supported by the similarity in levels of performance on both lists between this group and the sample of normal grade 4 subjects, this would indicate that the normal-hearing group also performed more poorly than the 66+ group on list C-1 but not on list I-1. Thus, results of the t tests confirm the suspicion that the lack

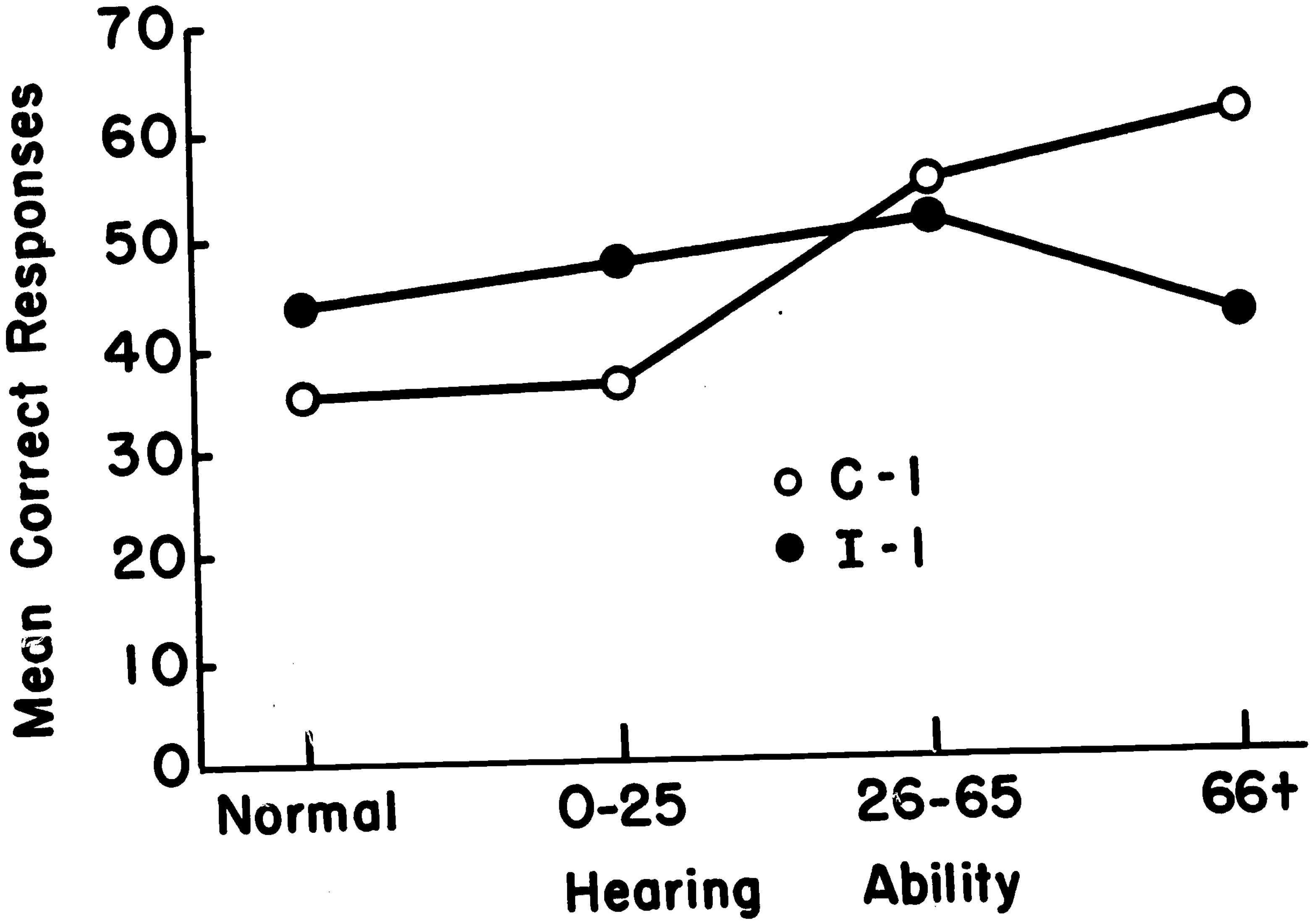

Fig. 2.2. Mean performance by hearing category on lists I-1 and C-1.

of significance for hearing-loss groups and for the interaction between groups and lists in the analysis of variance was influenced by the combination of small sample sizes and large within-groups variance.

To further assess the observed trend for increasingly better performance with increasing hearing loss on list C-1, regression coefficients for the two lists were calculated. The regression of performance on hearing-loss for list I-1 was -.07 which is not significantly different from zero; however, the value for list C-1 was .24 which is significant at the 5% level. The observed trend of better performance with increasing hearing loss on the list with consistent pairings was thus supported statistically using this approach. As would be expected, correlation coefficients agreed with the regression coefficients, _r_ for PTA and performance on list I-1 being -.10 and on list C-1 being .39. Again, only the latter value is significant at the .05 level. Corresponding correlations for age and performance were .51 and .18 for lists I-1 and C-1, respectively. The former is

significantly different from zero. The lack of significance for list C-1 assures the fact that age and hearing loss are not being confounded.

Learning curves for the two lists provide additional visual support for the hypothesis that hearing loss interacts with manner of pairings. Figures 2.3 and 2.4 show the learning curves for the four hearing categories for lists I-1 and C-1, respectively. Again the normal grade 4 samples are included, primarily for reference. As shown in these figures, the groups form two distinct clusters in rate of acquisition of list C-1 but are closely intermingled on list I-1. The upper curves in Figure 2.4 are for the two more severely impaired hearing categories, 26-65 and 66+ dB hearing loss, while the lower curves are for 0-25 dB loss and normal. These data suggest that a moderate or severe hearing impairment facilitates learning the consistent list, or, conversely, that subjects with normal hearing or with only very mild hearing losses perform less efficiently on that list. This clear separation in rate of acquisition as a function of hearing ability is in sharp contrast to the overlapping curves for list I-1, which indicate that the groups did not differ appreciably in rate of learning that list.

Errors. The kinds of errors made were examined to see if further differentiation between hearing and hearing-impaired children would be found. Twelve error categories were defined including omissions and various intralist and extralist intrusions similar to those used in Experiment 1. The most frequent error occurring in either group or individual testing was "no response;" this represented over two-thirds of the errors for any hearing category with either list. The next most frequent error category consisted of intralist nonrhyming response intrusions. Again, lists made no apparent difference. Such errors occurred about 20% of the time. These two classes of errors accounted for nearly 90% of the errors made. Thus, errors did not discriminate among either lists or hearing groups.

Discussion

The results of this study are somewhat tenuous but do tend to support the general hypothesis that hearing-handicapped subjects differ from normal-hearing subjects in the manner in which they manipulate verbal material covertly. In terms of the specific hypotheses tested in this experiment, the results are mostly negative:

(a) no significant difference in performance between lists with consistent pairings and with inconsistent

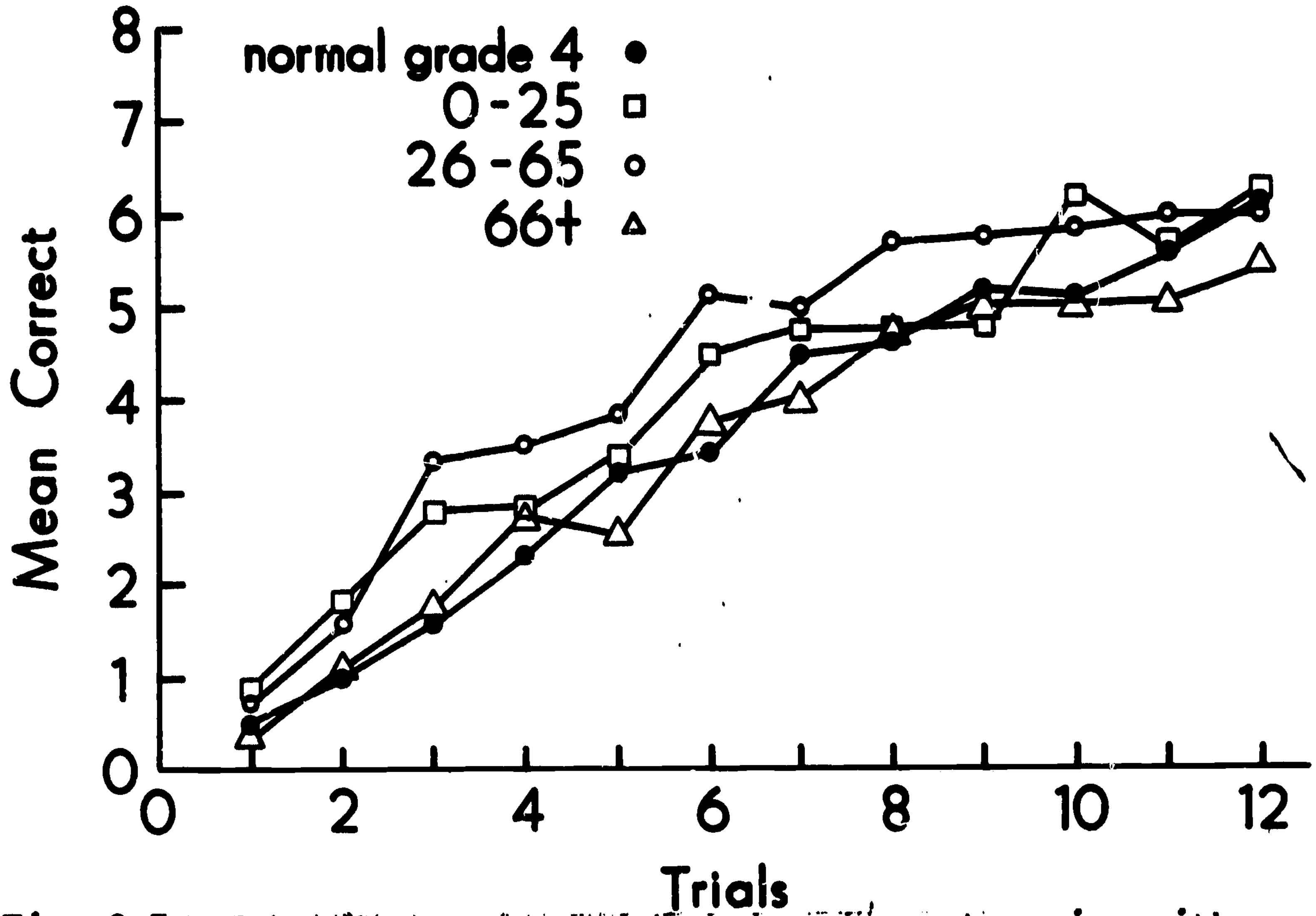

Fig. 2.3. Learning curves for four hearing categories with list I-1.

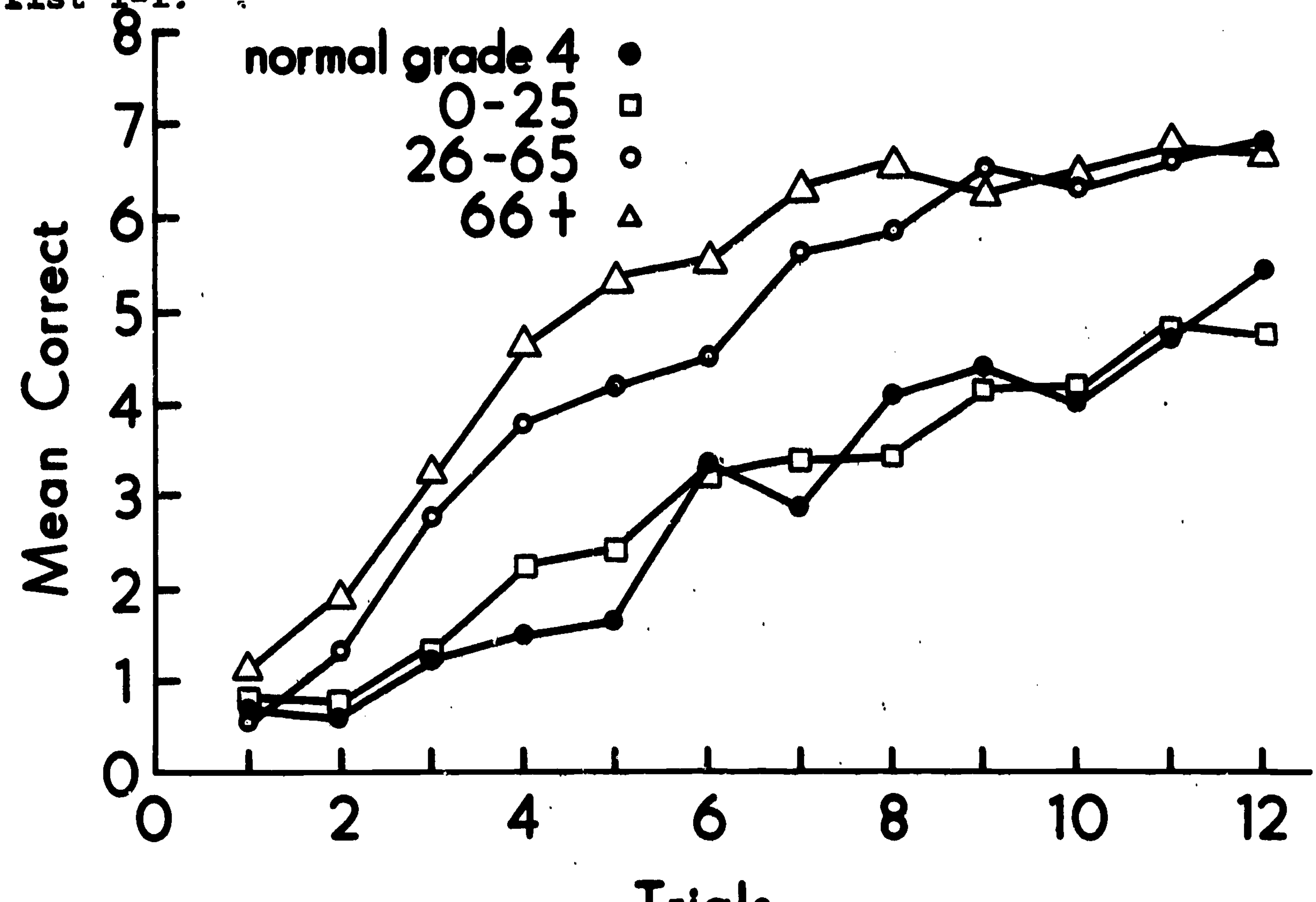

Fig. 2.4. Learning curves for four hearing categories with list C-1.

pairings was found for normal-hearing grade 4 children,

(b) subjects with severe hearing losses (66+ dB) differed significantly in performance on the two lists with consistent pairings producing better learning, and

(c) normal-hearing subjects did not differ significantly from hearing-impaired subjects on list I-1 but did perform more poorly on list C-1.

Thus, in terms of the initial hypotheses, only the prediction for list C-1 was supported statistically.

Although normal-hearing subjects failed to perform as suggested by Dallett's study (1966), a number of procedural differences may account for this. Dallett used homophonous stimuli (e.g., BOAR and BORE) while this study used rhyming stimuli (e.g., DOOR and MORE). These two situations are not entirely analogous since the rhyming stimuli provide more cues for discrimination than do homophonous words. The latter can be differentiated only on a graphic or a semantic basis while rhyming words differ also acoustically. Furthermore, Dallett used twelve word-pairs while eight were used in this experiment, making the task less difficult for adult subjects. However, for children an eight-item list may be harder than twelve items would be for adults. Data are not available relevant to this point. At any rate, list length is probably not the entire explanation for the lack of difference in performance on the two lists since the direction of the obtained difference is opposite to that expected. Both normal-hearing grade 4 subjects in group testing and the 0-25 dB hearing-loss subjects in individual testing exhibited a tendency to better performance on the list with inconsistent than consistent pairings. Thus, the anticipated interference effect with inconsistent pairings does not seem to hold in this study.

Two other procedural differences between Dallett's study and this experiment should also be noted. Trials-to-criterion were used by Dallett in contrast to total number of correct responses over a fixed number of trials. However, these two indices are inversely related and should not contribute to the discrepancies noted between the two studies; if anything, the trials-to-criterion measure should probably be less sensitive to differences than the mean-correct-responses index. The other difference lies in the age groupings used, college students vs. grade 4 children. It may be that the results obtained by Dallett cannot be generalized to younger subjects. This cannot be determined satisfactorily with the data at hand; however, the fact that children with severe hearing losses performed differently suggests that this explanation is also invalid. To

find hearing-handicapped children performing better than normals on a verbal task is contrary to all previous evidence and indicates that something about the materials themselves produced the differential performance.

The most significant finding emerging from this study is the fact just mentioned, that a hearing loss seemed to insure a trend to better performance, at least on the consistent list. This result, coupled with a clear distinction in the rate of learning that same list by subjects with and without a significant hearing loss, provides additional support for the basic hypothesis in this project. It had been postulated that normal-hearing and hearing-impaired differ in the way they manipulated verbal material internally. Certainly, the data from list C-1 indicate that the greater the hearing loss, the less interference obtained from acoustically similar words. Why this same effect was not noted with the companion list, I-1, is not fully understood. The same words were used in either list; interference from acoustic similarity was found with both sets of pairings by Dallett. Thus, reduction in interference was expected with both lists with hearing-handicapped children but was not obtained.

These data lend themselves to another interpretation. It may be that the dimension of acoustic similarity can be used by hearing-handicapped children to facilitate learning under certain conditions rather than producing interference as in normal-hearing subjects. In other words, the same experimental variable might serve both to interfere with and to enhance learning as a function of hearing ability.

Let us look at the data from this viewpoint. The I-1 list was equally difficult for both hearing and hearing-impaired subjects. One must reject the hypothesis that acoustic similarity is operating in the same manner in both kinds of subjects to produce the same amount of interference since this would be incompatible with the differential performance on list C-1. Without a control list, it is difficult to assess whether interference is operating in list I-1. The error analysis failed to show any tendencies for rhyming responses to be emitted as errors by any of the groups for either list. Thus, it is possible that interference on list I-1 was minimal as compared to a control list for all groups.

Perhaps hearing and hearing-handicapped children approached both lists in unique fashions. Normal-hearing children viewed the I-1 materials as they were presented and found the list difficult due to list length and perhaps also due to confusions from the acoustic similarity dimension. When presented with the C-1 list, difficulty remained about the same suggesting that list length was

the relevant variable and that acoustic similarity played a minor or a fixed role in the learning of the two lists by children without hearing impairment. Hearing-handicapped subjects, on the other hand, found I-1 difficult due to list length, also, but the dimension of acoustic similarity is assumed not to contribute to the difficulty. It was an irrelevant dimension. When the pairings in the list became consistent, however, the dimension of acoustic similarity was now both relevant and facilitating to the hearing-impaired subject. He was able to take the rhyming qualities of the materials as cues to the pairings; having learned one pair, a pattern was available for learning another pair which was acoustically similar. He had less trouble with instrusions by the incorrect rhyming response because he processed the words initially in a manner which did not use the acoustic properties of the materials (i.e., he "thought" of the words not according to how they sound but according, perhaps, to how they looked). Since the items had already been differentiated along some other dimension, auditory similarity aided learning by providing cues for association without introducing errors through stimulus or response generalization. The latter, if it were to occur, would be along lines related to the primary dimension by which the items are ordered or perceived <u>by the subject</u>.

Thus, it is postulated that the two kinds of children (hearing and hearing-impaired) approached the task differently. Hearing children transformed the words by implicit vocalization to auditory units; hearing-handicapped children processed the printed words by some other system. The difficulty of the task forced both groups to search for additional cues or strategies which would aid in learning. The normal-hearing were basically unsuccessful in finding any facilitating aspects in either list within the time allotted. The hearing-handicapped also found no aids in learning the list of inconsistent pairings but did find that the sounds of the words helped in learning the consistent pairs.

The basic hypothesis with which this project was undertaken should be amended now to state that, given meaningful material, (a) normal-hearing individuals process verbal material auditorily as a primary step while (b) hearing-handicapped individuals process verbal material in a visual (or other nonauditory) manner initially. When the task requires elaboration of these procedures, (c) the hearing child then probably turns to a spelling or visual appearance as a secondary attribute and (d) hearing-impaired children attend to the auditory dimension next. This last step is only possible because of the auditory training which the child with a severe hearing loss has obtained. Without auditory training, the sounds of the words would

not be a relevant dimension to the hearing-impaired. Thus, it may be said that, to the normal-hearing child, a word is "thought of" first as a pattern of sounds and then as a set of orthographic symbols. In contrast, a word to a person with a congenital hearing loss is "thought of" first as a set of letters and then, secondarily, as a pattern of phonemes and the latter is only learned through auditory training. Ultimately, of course, both kinds of subjects "think of" a word in terms of its meaning.

Experiment 3

Short-Term Retention of Verbal Material as a Function of Hearing Ability

Children with severe hearing impairments which predate the development of language have considerable difficulty in mastering reading. This deficiency manifests itself in generally poorer academic performance as compared with normal-hearing peers. One possible explanation for this difficulty may be that an early hearing loss results in a basic inability to manipulate verbal material covertly. The hearing child, or adult for that matter, may employ implicit oralization in "thinking" verbally. If such a process does in fact occur, it may be derived from the oral language to which normal-hearing subjects are initially exposed. This early experience may form the basis for later internalized manipulations of language elements. In contrast, the child with a congenital hearing loss is deprived of the experience of oral language and presumably fails to develop this model for internalized verbal behavior. When learning to read, he has no established language system to which he can relate these new experiences. This is not the place to conjecture what might be substituted for the spoken word in the mind of a deaf child; one can only conclude that whatever process he is using, it apparently is inefficient since he is retarded in reading and other language skills.

Up to this point we have been concerned primarily with acquisition of verbal material. However, memory is another aspect of behavior which might distinguish between hearing and hearing-impaired subjects. As mentioned previously, the bulk of the experimental evidence seems to point to an acoustic memory in hearing subjects. Gibson et al. (1964) favored a syllabic-encoding explanation for their data. Numerous short-term memory studies (e.g., Conrad, 1962, 1964; Wickelgren, 1965a) also support the hypothesis of acoustic memory in normal-hearing subjects. Several studies comparing normal-hearing and deaf subjects on various dimensions suggest that the two groups differ in kind rather than degree. Conrad and Rush (1965) found, in a short-term memory

task, that the deaf made errors which were regular but along a dimension which was not acoustic, contrary to the behavior of normal-hearing subjects. Odom and Blanton (1967) found deaf and normals differed in the way they stored word phrases. The same two authors in another study (Blanton & Odom, 1968) showed that deaf and normal subjects also differ in processing CVC trigrams with high or low pronunciability ratings, concurring with previous findings by Blanton and Nunnally (1967). Thus, the hypothesis that hearing and hearing-impaired individuals may differ qualitatively in the memory process is not without an empirical basis.

This experiment did not attempt to examine the dimensions of the memory process; that problem was the topic of the two preceding experiments. Rather, it attempted to gauge the relative efficiency of the memory process in subjects with normal or impaired hearing. Regardless of whether the hypothesized qualitative differences in cognitive functioning were supported by the data or not, efficiency in retention is of both experimental and educational interest. If qualitative differences were demonstrated in the way in which verbal material is processed internally, this experiment would serve to compare the effectiveness of the two systems. If hearing and hearing-impaired groups performed alike on this task even though they exhibited qualitative differences, it might be better to leave their respective systems intact and attempt to modify instead our educational procedures. It may even be that the systems are not amenable to change after a certain period of time. However, if qualitative differences in acquisition of verbal material were accompanied by quantitative differences in storage-retrieval, with the hearing-impaired being less efficient, then the obvious conclusion is to seek ways of altering the information-processing system of the hearing-impaired. On the other hand, even if qualitative differences were not indicated, one still would be interested in whether the hearing-impaired retained verbal material as well as those with normal hearing under controlled experimental conditions.

Murdock (1961) showed that short-term memory was similar for equal quantities of either unrelated letters of the alphabet or unrelated monosyllabic words. Recall of a set of three letters or a set of three words did not differ as a function of time. This finding was consistent with Miller's "chunking" hypothesis (1956) which can also be used to support the hypothesized auditory nature of mental functioning since it is only orally (aurally) that a word and a letter can be equivalent.

If verbal memory depends upon auditory attributes of the stimuli, then a hearing impairment would change the process. The impairment would not allow efficient processing of auditory material but instead would distort this dimension of

language. Cues for storage and retrieval would have to come from other attributes of the stimuli. The fact that normal-hearing subjects apparently select the auditory dimension over other attributes suggests that acoustic cues are either more convenient (i.e., are directly available) or else are more suitable for such purposes (i.e., are more efficient in terms of "chunking"). Therefore, it was hypothesized that hearing-handicapped subjects would perform more poorly on a short-term memory task with words as stimuli than would their normal-hearing counterparts since they are forced to use less favorable cues for memory. Murdock's study (1961) served as the model for this experiment with modifications made in the interpolated activity appropriate for the ages of the subjects used.

Method

Materials. Monosyllabic words with A and AA frequency ratings (Thorndike & Lorge, 1944) were randomly assigned to triads with the restriction that associations within a triad were minimal. A total of 213 words were used to form 71 triads, using each word only once. Appendix C contains a list of all the triads used. Two- and three-digit numbers were selected randomly and served to initiate the interpolated activity (counting).

Digits and triads were photographed on a 16 mm film strip in reverse image. The film strip started with several frames of digits to give the subject practice with interpolated activity. The remainder of the film strip consisted of a repeating sequence of triad-digits-blank frames. No triad appeared more than once. The film was projected upon a lenticular screen using the Tel-n-See projector. The timing intervals used were 2-1-5 seconds; i.e., the triad was exposed for 2 seconds followed by the digits for 1 second followed by a blank frame for 5 seconds. The 5 seconds interval for the blank frame gave the experimenter time to stop the tape and thus assume manual control of the delay interval.

A Seth-Thomas Electronic Metronome, Model E962-000, was used to regulate the rate of counting by the subject and to time the duration of the delay intervals. This instrument has both a visual and an auditory component. A rate of one beat per second was used. The intensity of the click was adjusted to a level that was clearly audible to the subject, or, if this was not possible, the subject was instructed to count in time with the flashes. The metronome was positioned near the screen where it was easily observed by both experimenter and subject.

Subjects. A total of 53 subjects was used in this experiment. Table 3.1 summarizes the relevant data for the subjects in each hearing category. These categories are the same as those used in Experiment 1, conforming to the meaningful groupings of normal hearing and mild, moderate, severe and profound hearing losses.

TABLE 3.1

Summary of the Five Hearing Categories From Experiment 3 in Terms of Age, Sex, Hearing Level, and Reading Level

Group	N	Age	Sex M	Sex F	PTA	RL
Normal	8	9.[illegible]6	5	2	-	4.00
0-25	13	11.08	5	8	8.46	5.02
26-65	14	11.50	10	4	46.28	4.01
66-90	10	13.40	8	2	80.80	4.19
91+	8	13.25	1	7	102.00	3.62

Procedure. Practice with interpolated activity preceded the task. The subject was instructed to repeat the digits as soon as he saw them on the screen and then to count forward by "ones" in time with the metronome until the experimenter said "Stop." With deaf subjects, the experimenter said "Stop" and simultaneously touched the subject on the shoulder. Practice with counting was continued until the subject could perform the interpolated activity as directed. Pilot data had indicated that counting forward by "ones" was a satisfactory interpolated activity for this age group. Talland (1967) reported that any interpolated activity was effective so long as it prevented rehearsal and interrupted the original task set. These effects seemed to be achieved when counting by "ones." Crowder (1968) reported that interpolated-task performance bore no reliable relationship to level of recall. Thus, counting backwards by threes or fours as Murdock did (1961) could have been used with children. However, there seemed no reason to require such a difficult task of them and raise their frustration level.

The subject was next instructed about the triads and the experimental task. The first five presentations were discarded as practice although the subject was not aware of this. The experimenter determined that the subject was fully familiar with the procedures before collecting data.

Delay intervals of 0, 3, 6, 9, 12, and 18 seconds were used as in Murdock's study (1961). The delays were randomized in blocks of six and assigned to triads. Two different orders of delay intervals were used to avoid any constant error due to triad-interval combinations. Subjects were alternately assigned to one of the two orders as they appeared.

The tape recorder controlling the film advance was stopped by the experimenter during the blank frame and the delay interval was timed by watching the metronome. All delay intervals were thus controlled by the experimenter and began with the first flash of the metronome following the offset of the digits frame. For 0 second delay, the experimenter said "Stop" at the first flash following the offset of the digits; for longer delays, the first flash was counted as one second of delay. A recall interval of 10 to 12 seconds preceded presentation of the next triad. A rest period of 5 minutes was given halfway through the session. Each delay interval was presented 10 times giving data from each subject for 60 triads. In the event that a triad was considered "invalid" for some reason (e.g., subject did not begin counting immediately, an error occurred in timing the delay, etc.), another triad was assigned to that same delay interval later in the session. All testing was conducted individually in a single session lasting about 40 minutes.

The experimenter at the time of testing scored correct responses ignoring order. Each session was also tape recorded in its entirety with one of the cassette recorders to allow for later re-evaluation and to provide data for latency-of-response measures and for error analyses. The responses of deaf subjects were repeated by the experimenter to insure correct interpretation. The experimenter was experienced with deaf speech and used lip and mouth movements made by the subject to aid in identifying the phonemes. A "feel" for the quality of speech of each subject was also gained during the practice period and audiometric screening. By repeating the words after the subject, it was possible both to verify the subject's intentions and to provide a response of good quality for the recording.

Results

Correct Responses. The total number of triads correctly recalled by each subject at each delay interval was determined. Inspection of the data revealed a positive skew with many values near zero. The highest number of triads recalled by any subject for a given delay interval was 9 out of a possible 10; this score was achieved by several children in

groups 0-25 and 26-65 dB hearing loss at short delays. To facilitate analysis the raw scores were transformed using $\sqrt{X} + \sqrt{X+1}$ (Winer, 1962). Subsequent examination of the data indicated that the transformation had been effective in reducing skew. Table 3.2 summarizes both the raw and transformed data for all groups and delay intervals.

TABLE 3.2

Mean Correct Triads and Standard Deviations of Raw (R) and Transformed (T) Data for Five Groups and Six Delay Intervals

Group		Delay 0	3	6	9	12	18
Normal	$\bar{X}_R$	3.25	2.12	2.00	1.50	1.62	1.88
	SD_R	1.58	1.96	1.07	1.51	2.07	1.64
	$\bar{X}_T$	3.78	2.82	3.08	2.46	2.48	2.78
	SD_T	.85	1.56	.67	1.31	1.49	1.28
0-25	$\bar{X}_R$	6.15	3.15	2.38	2.08	1.46	1.85
	SD_R	2.19	2.08	2.10	2.25	1.56	1.34
	$\bar{X}_T$	5.07	3.55	3.05	2.79	2.42	2.80
	SD_T	.95	1.40	1.44	1.52	1.29	1.15
26-65	$\bar{X}_R$	3.50	1.57	1.36	1.00	1.29	1.14
	SD_R	2.35	1.74	1.91	1.84	1.33	1.17
	$\bar{X}_T$	3.74	2.53	2.27	1.88	2.38	2.29
	SD_T	1.39	1.28	1.39	1.39	1.09	1.01
66-90	$\bar{X}_R$	3.60	1.70	1.10	2.10	1.50	1.70
	SD_R	2.27	1.42	1.52	2.23	1.35	1.25
	$\bar{X}_T$	3.88	2.66	2.03	2.81	2.52	2.74
	SD_T	1.19	1.24	1.36	1.53	1.18	1.06
91+	$\bar{X}_R$	4.75	2.25	2.38	2.00	1.50	2.25
	SD_R	1.39	2.19	1.60	1.51	1.07	1.39
	$\bar{X}_T$	4.54	2.86	3.00	2.96	2.66	3.13
	SD_T	1.47	1.65	1.20	1.08	1.17	1.06

Figures 3.1 and 3.2 illustrate the performance as indexed by raw and transformed scores, respectively. As shown there, the transformation minimized the contributions of extreme scores. Notice in particular how the spread of the groups at 0 second delay was reduced by the transformation.

Analysis of variance of the transformed data showed that delay intervals were the only significant source of variance as presented in Table 3.3. Scheffé post mortem analysis of the main effect due to delays showed the recall at 0 second was significantly greater than at all other intervals. The poorest recall was associated with

TABLE 3.3

Analysis of Variance of Correct Responses (Transformed Data) for Five Hearing Groups and Six Delay Intervals With Scheffé Results for Delays

Source	df	MS	F
Between Ss	52	.56	
Hearing (H)	4	7.20	1.32
Error (b)	48	5.44	
Within Ss	265	1.25	
Delay (D)	5	22.90	27.93**
HxD	20	.98	1.20
Error (w)	240	.82	
Total	317		

Summary of Scheffé:[a]

	Delay					
	00	03	18	06	09	12
$\bar{X}_T$	4.22	2.90	2.70	2.65	2.53	2.47
$\bar{X}_R$	4.32	2.17	1.70	1.81	1.70	1.45

**p <.01

[a] Lines connect nonsignificant differences at 5% level

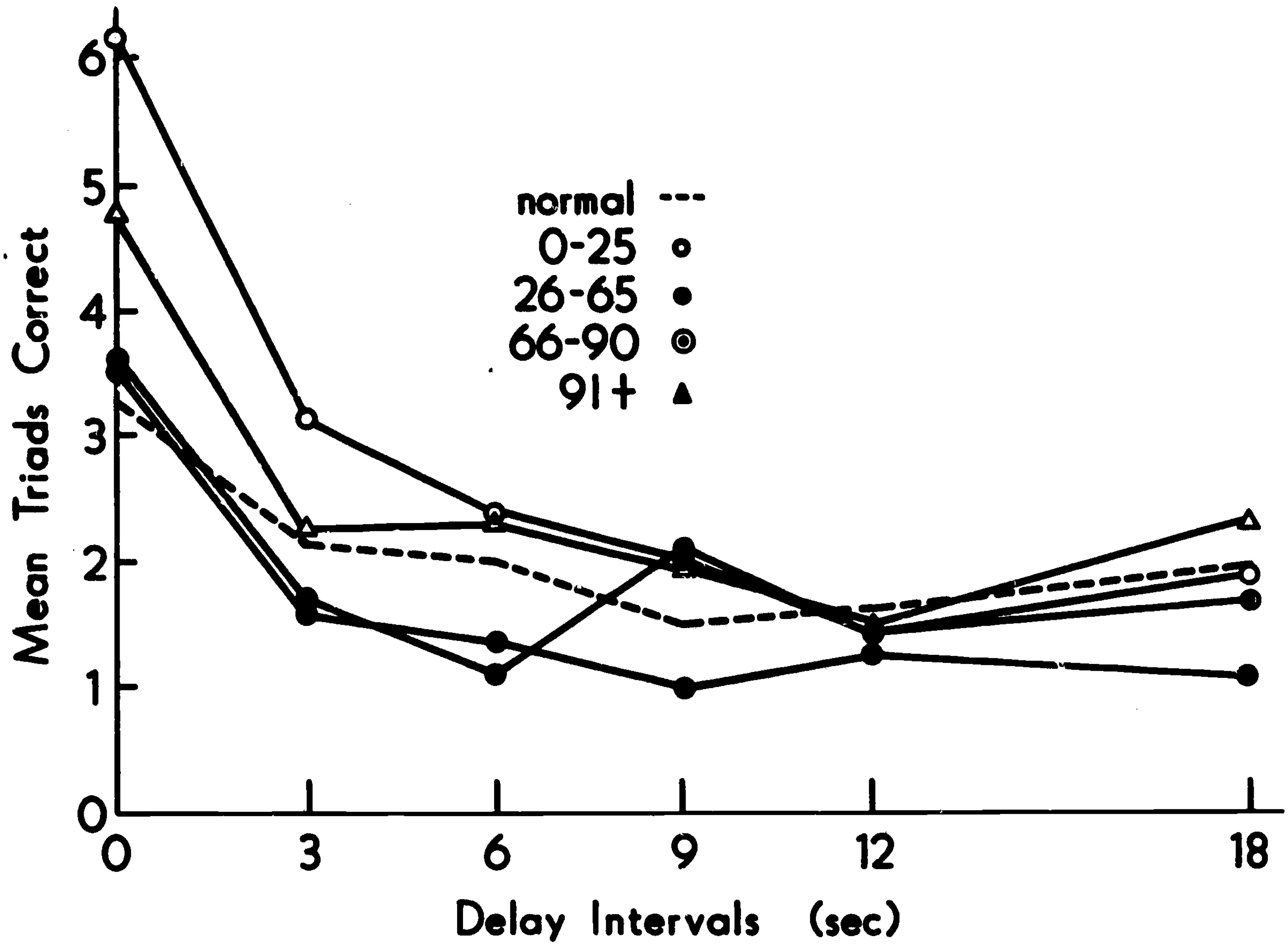

Fig. 3.1. Mean correct triads for five hearing groups across six delay intervals (raw data).

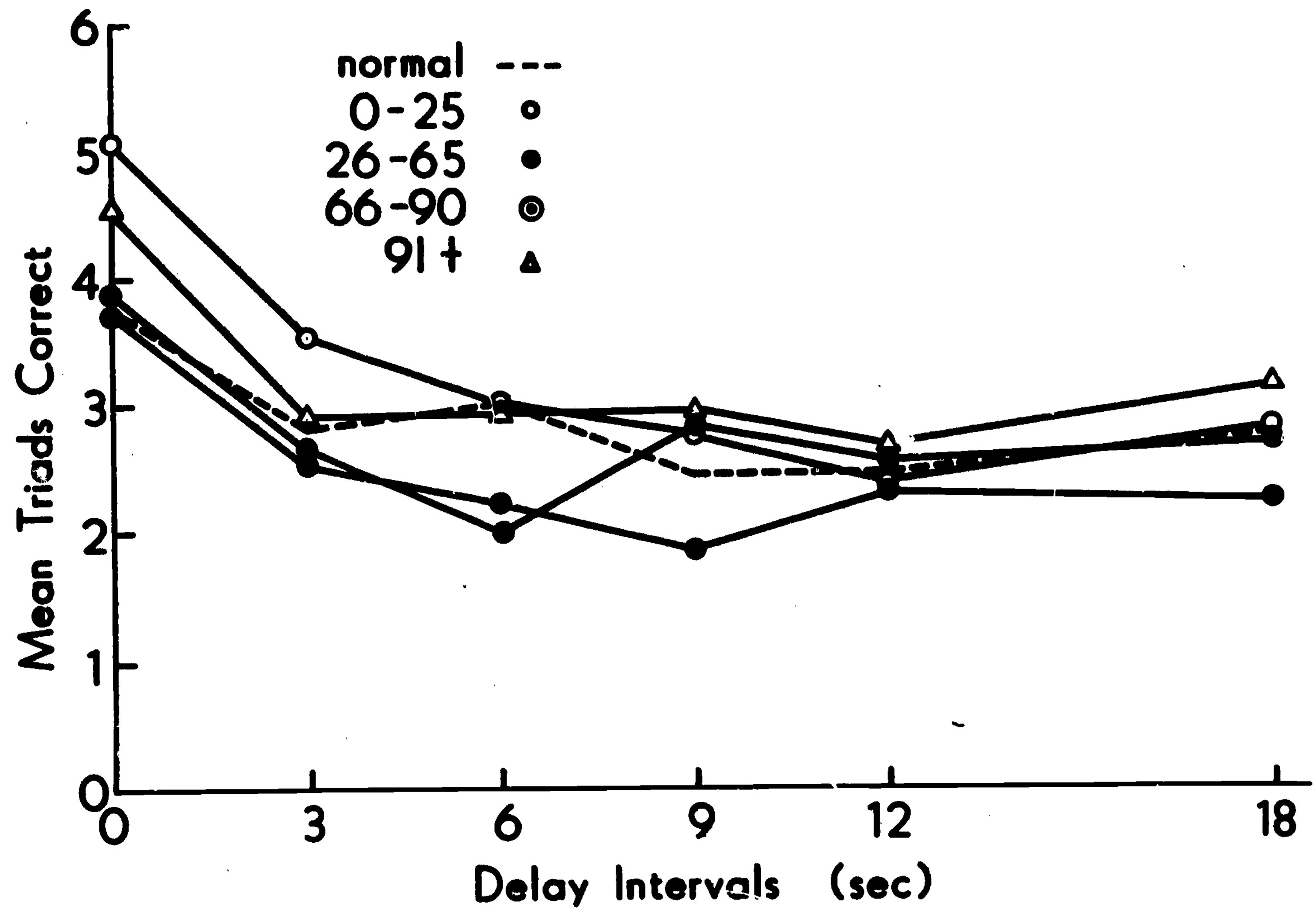

Fig. 3.2. Mean correct triads for five hearing groups across six delay intervals (transformed data).

the 12 second delay interval, not with the 18 second delay as would be expected from the Murdock study (1961). Recall at 18 seconds was not significantly different from that at 3 seconds nor from that at 6, 9, or 12 seconds although the retention after 3 seconds was significantly different from that for the 6, 9, and 12 second intervals. The Scheffé comparisons were based upon transformed values; however, nearly the same ordinal relationship among the six delay intervals was obtained when the means for the main effects of delay were calculated for the raw data, the only difference being a reversal of positions for the 6 and 18 second intervals. These are also summarized at the bottom of Table 3.3.

The preceding analysis dealt only with completely correct triads. However, many triads were partially correct, containing one or two words which were correctly recalled. Table 3.4 shows the distribution of triads in which all three words were recalled correctly, and those with two words correct, one correct, or no words correct for the five groups. Figure 3.3 illustrates these data. As indicated there, with the exception of the 26-65 dB group, all

TABLE 3.4

Mean Number of Triads With Three, Two, One, or Zero Correct Items for the Five Hearing Categories Over Delay Intervals

Hearing Category		Items Correct per Triad 3	2	1	0
Normal	$\bar{X}$	12.38	21.50	15.25	10.87
	SD	6.65	5.35	4.65	6.81
0-25	$\bar{X}$	17.08	17.38	15.38	10.16
	SD	3.56	4.43	7.56	5.22
26-65	$\bar{X}$	9.86	14.57	19.57	16.00
	SD	8.53	5.60	5.49	8.68
66-90	$\bar{X}$	11.70	18.90	17.30	12.10
	SD	8.17	6.08	6.31	4.17
91+	$\bar{X}$	15.13	20.88	15.50	8.49
	SD	5.74	4.02	5.42	6.26

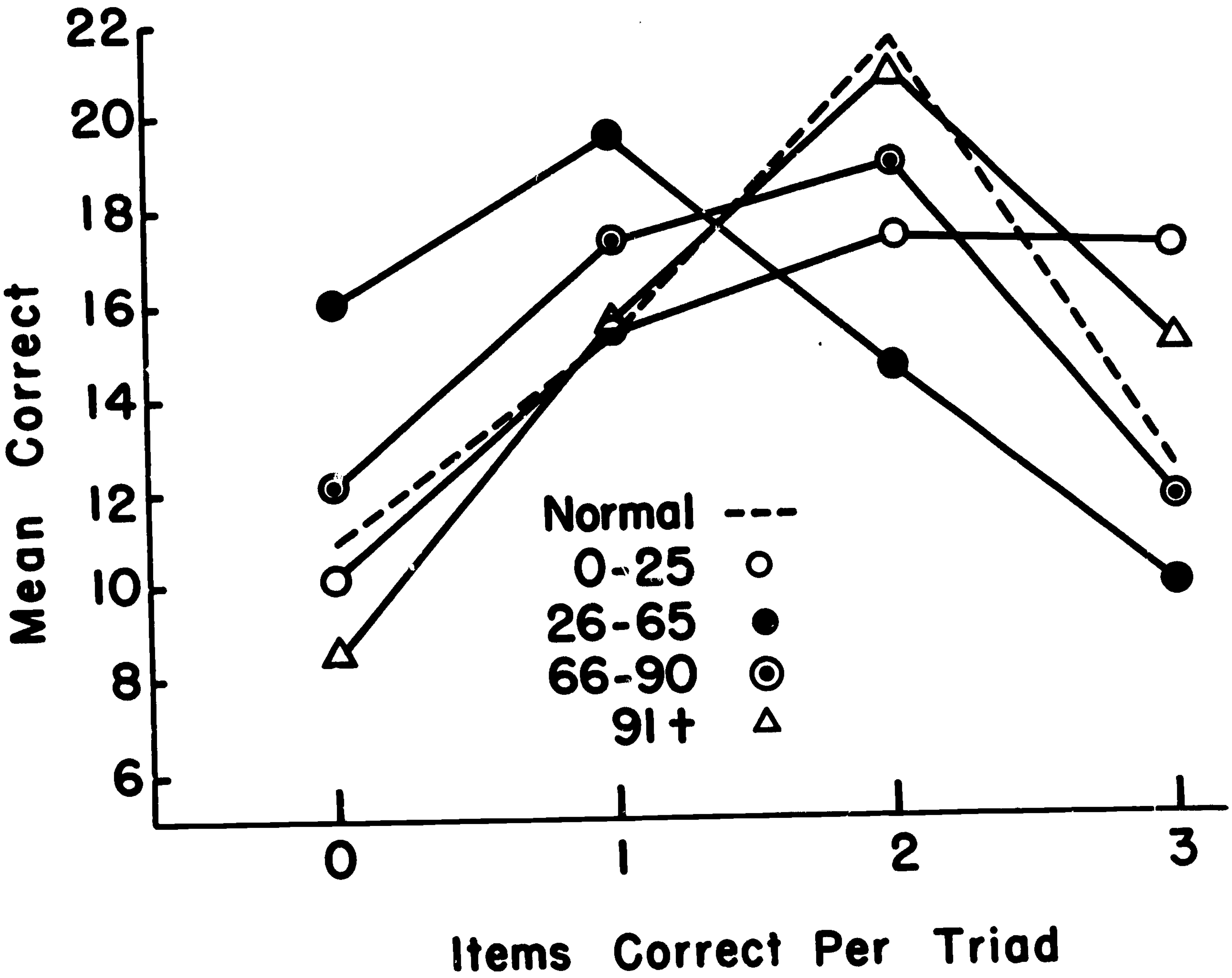

Fig. 3.3. Mean number of triads with 0, 1, 2, or 3 items correct for each hearing category.

groups tended to recall correctly two of the three items in a triad most frequently. The 26-65 dB group recalled only one of the items usually. Only the data for two words in a triad showed a significant difference among groups; F (4,48)=3.18, p <.05. Tukey (a) comparisons (Winer, 1962) showed that the 26-65 dB group had significantly fewer triads with two correct words than did the normal and 91+ dB groups; all other differences were not significant.

Errors. The errors made were examined in two different ways. Error categories were established similar to those used in the two preceding experiments in which the broad categories of omissions, intralist and extralist intrusions were divided into finer classes. Omissions consisted of no

response (NR) or its equivalent, e.g., the subject said "I don't remember." Four kinds of intralist intrusions were distinguished: words from the triad which immediately preceded the one in question (triad minus one, or T-1), words from the next preceding triad (T-2), words from the third preceding triad (T-3), and words from triads beyond the third preceding one (T-4+). Two kinds of extralist intrusions were defined: errors that were "obviously" associated with the correct word (Like), and errors that bore no obvious relationship to the correct one (Unlike). Obvious associations included formal similarity (e.g., BLACK for BACK, COULD for CLOUD) and semantic similarity (DROVE for DRIVE, DOES for DONE).

The five groups of subjects exhibited the same general patterns in kind of errors made. As shown in Table 3.5, the majority of errors made were omissions as in the other two experiments. Intralist intrusions of all kinds formed the next largest source of errors with most of these coming from triads beyond the third preceding one (T-4+). The two classes of extralist intrusions contributed relatively little to total errors. The differences between groups in total number of errors reflect their relative performance in retaining different amounts of information from a triad. As shown in Figure 3.3, the 26-65 dB group had more triads in which no items were correctly recalled, thus adding three errors per triad to their total. The 0-25 dB group increased their error total by recalling two items in a triad less frequently than the other groups, excepting 26-65 dB. It is interesting to note that the normal-hearing group and the 91+ dB hearing loss group parallel one another quite closely in both kinds of errors and number of triads with 0, 1, 2, or 3 items correct.

Errors were also examined as to position within the triad. The position of the <u>error</u> in triads with two correct items (diads) and the position of the <u>correct</u> word in triads where only one word was recalled (monads) was determined for each of the hearing categories. Both the primacy-recency effect and studies regarding scanning direction (Haber, 1964; Harris & Haber, 1963; Cohen & Musgrave, 1966) would predict more middle position errors than terminal (initial or final word) errors. However, the two differ with regard to terminal errors; primacy-recency would predict fewer final than initial errors while scanning direction would expect fewer errors in the initial than in the final position.

Figure 3.4 presents graphically the data from monads and diads for the five categories of hearing loss. Again it must be emphasized that the position of the single error is plotted for diads and the position of the single correct item is plotted for monads. Thus, the monad data provide

TABLE 3.5

Frequencies of Different Classes of Errors Made by Each of the Five Hearing Categories

Errors	Hearing Categories: Normal	0-25	26-65	66-90	91+
Omissions	306 (55%)	575 (57%)	632 (56%)	545 (68%)	452 (74%)
Intralist	155 (28%)	232 (23%)	272 (24%)	129 (16%)	82 (13%)
T-1	44	65	63	38	30
T-2	17	26	28	18	9
T-3	6	20	18	10	6
T-4+	88	121	163	63	37
Extralist	97 (17%)	207 (20%)	226 (20%)	128 (16%)	78 (13%)
Like	48	110	99	56	41
Unlike	49	97	127	72	37
Total	558	1014	1130	802	612

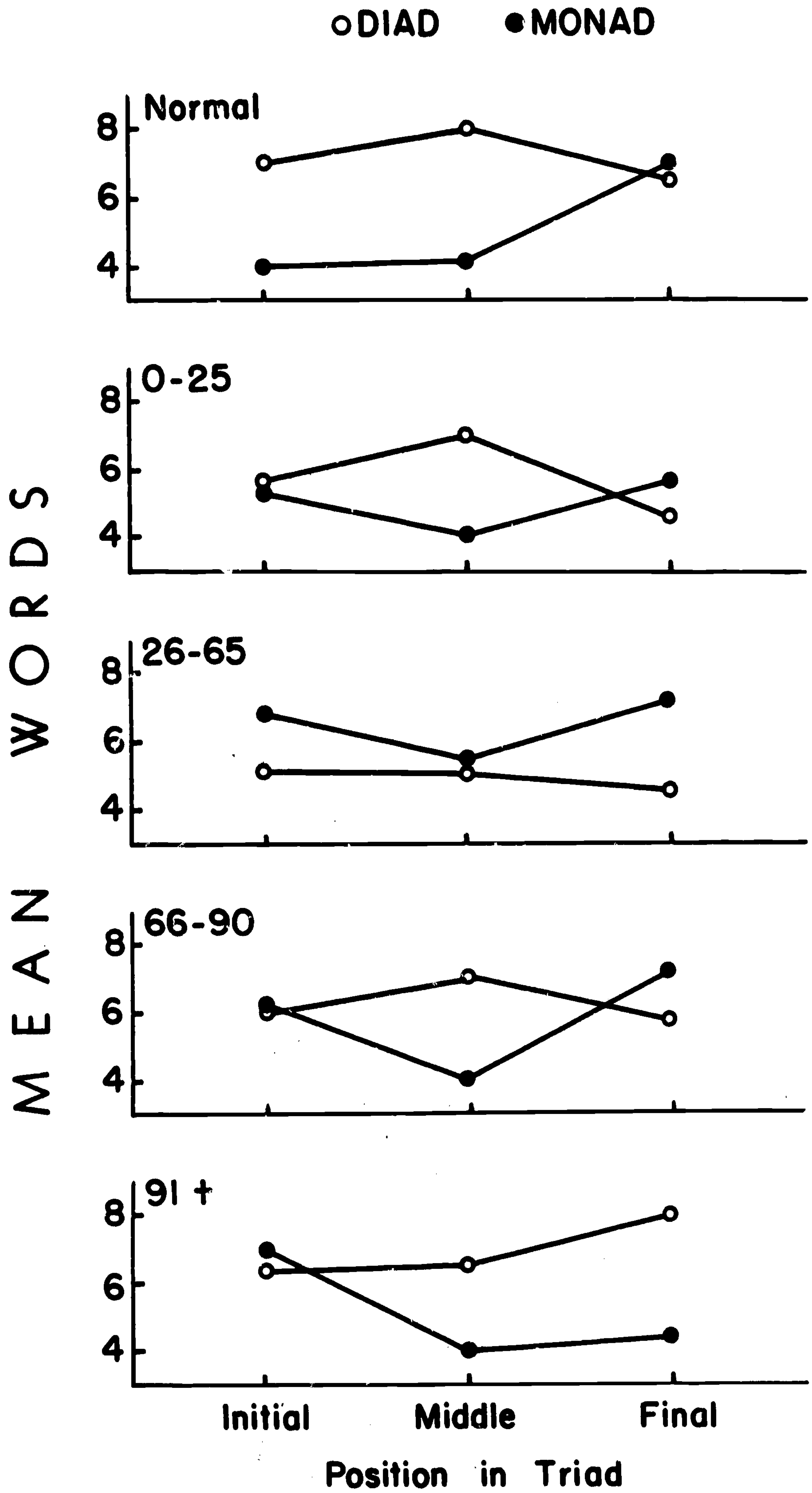

Fig. 3.4. Mean errors by position in diads and mean correct responses by position in monads for five hearing categories.

information concerning errors only by inference. Where more correct items occur, there are correspondingly fewer errors. Ideally, the two curves should be mirror images of one another and, in fact, they approximate this condition in all but the 91+ dB group.

Upon examining Figure 3.4, it is apparent that more errors (fewer correct items) occurred in the middle position in all groups with the minor exception of the normals who showed slightly fewer correct items (monads) in the initial than in the middle position (means were 4.00 and 4.12, respectively). Data concerning terminal position indicate that in the first four groups (normals through 66-90 dB) the monad and diad information reinforce one another; in those groups better performance was obtained consistently with the final item than with the initial word. Thus, recency effects predominate with these groups. In contrast, the group with 91+ dB hearing loss shows the opposite pattern with stronger primacy than recency effects. The effects of scanning direction could explain these data but do not seem adequate to account for the differential performance of this group when compared with others. All groups, it will be remembered, had been matched on reading ability and scanning direction is felt to be a learned phenomenon related to reading.

Latencies. The latency to respond was determined to the nearest .5 second for all triads to which the subject made any kind of response, whether right or wrong. Tapes for eight subjects were defective and could not be evaluated for latencies; these subjects were distributed across all groups. Mean latency-of-response scores were obtained for each subject at each of the six delay intervals for triads that were entirely correct and for triads that were incorrect. The means of these scores were then determined for each of the five hearing ability groups for both correct and incorrect triads. Figures 3.5 and 3.6 present the data for the correct and incorrect triads, respectively. As shown there, no clear trend existed between latency to correct response and delay intervals, contrary to the findings of others (Murdock, 1961), although the slope for latency to incorrect responses does appear to rise slightly with increased delay for all groups. In general, the latencies were longer for incorrect than for correct responses for all groups, consistent with findings by Talland (1967), the only exception being the 6 second delay data for the 26-65 dB group. This was due primarily to one subject who had several extremely long latencies before emitting incorrect responses at that time interval only. The latency-to-respond data failed to discriminate among the hearing groups in any important respect.

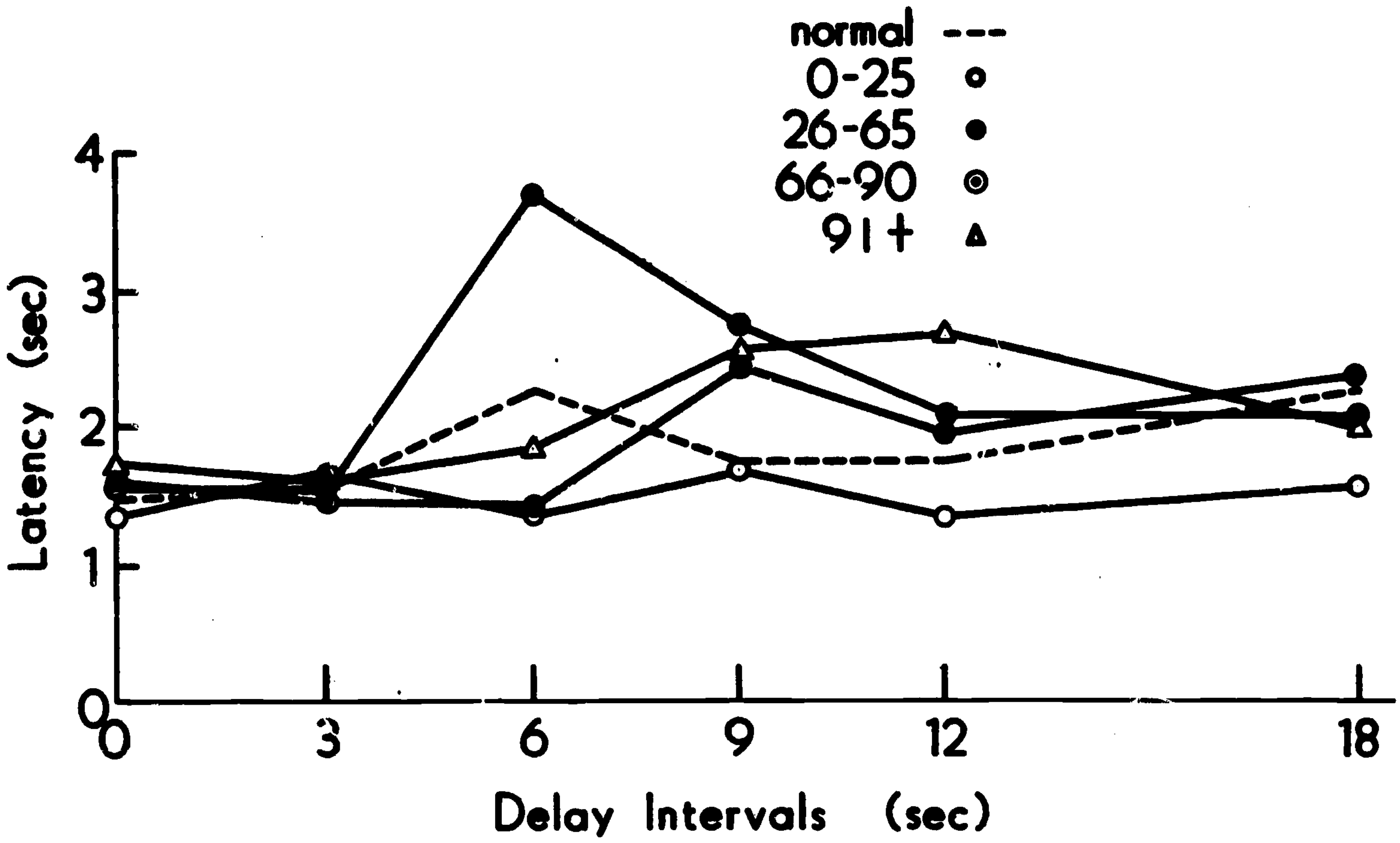

Fig. 3.5. Mean latency to correct response for five hearing groups at each delay interval.

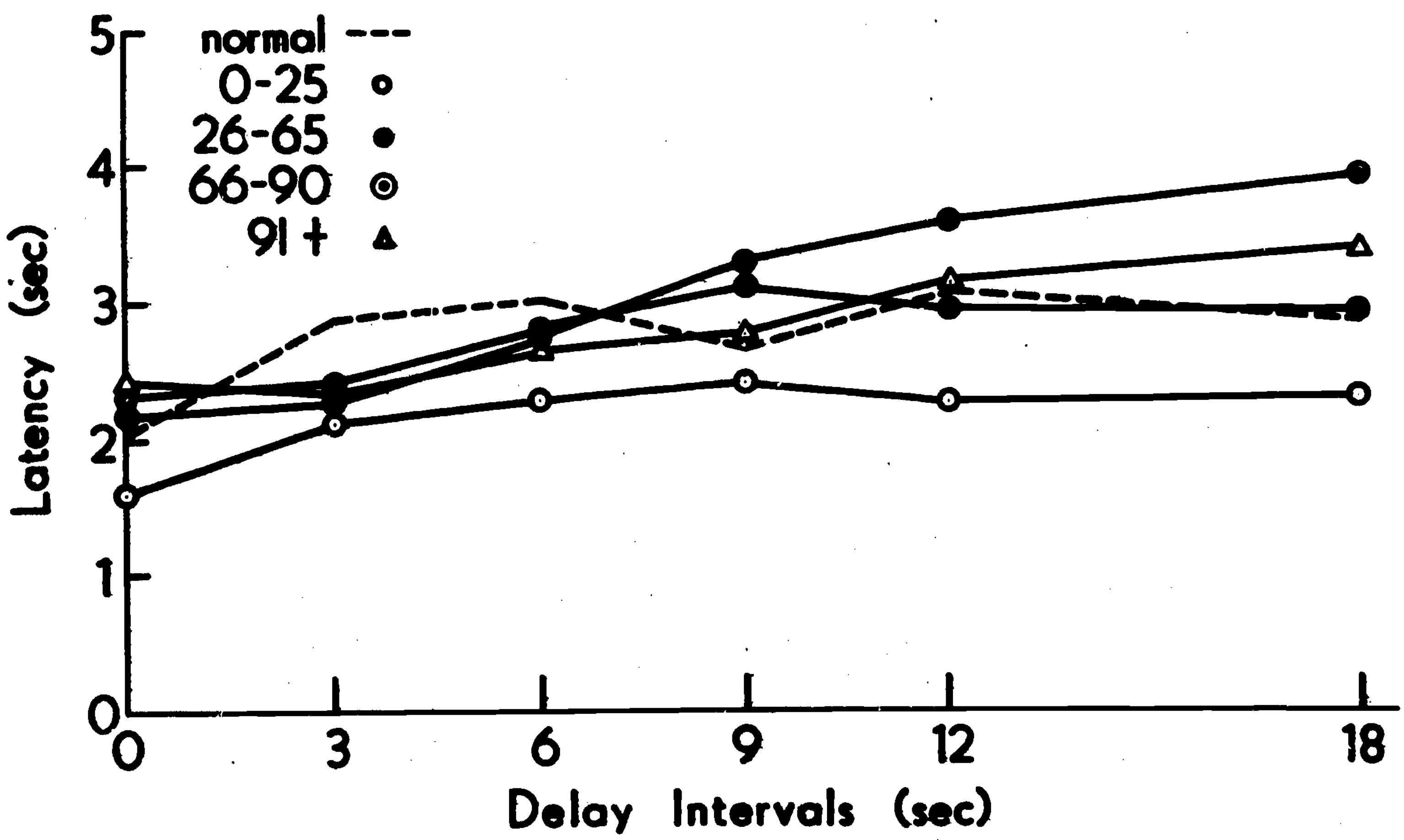

Fig. 3.6. Mean latency to incorrect response for five hearing groups at each delay interval.

Discussion

The results of this experiment indicate that short-term verbal memory is functionally the same in children with normal or with impaired hearing. In general, neither in retention, errors, nor latency of response were significant differences obtained among the groups. The only group which exhibited a strong tendency to diverge from the pattern was that with 26-65 dB hearing loss. No explanation for their behavior is apparent. Further studies will have to be conducted to determine whether this particular sample was merely showing extreme chance error or whether the population with that degree of hearing handicap does in fact differ on this kind of task from those with either less or more impairment.

These findings were surprising in view of the fact that decreased language skills are associated with increased hearing loss. Equating the groups on reading level should not have attenuated differences in verbal ability. Matching was not precise and, furthermore, reading levels assess comprehension and vocabulary skills while the task used in this study was measuring efficiency of storage and retrieval of words. The two dimensions, logically, would appear to be orthogonal or nearly so. Reading levels were used primarily to insure familiarity with the words used in the task since meaningfulness is a significant factor in acquisition and retention.

It would seem then, from these data, that the hearing-handicapped are equally as proficient as normal-hearing subjects in storing and retrieving words, at least under the conditions of this study. How this is accomplished has not been answered. This experiment was not designed to inquire into the particular modes of memory but was intended to assess differences in performance. If the hypothesis of an auditory storage is valid for normal-hearing subjects, then the hearing-impaired are either using the same memory process or else are employing another process with equal efficiency. Post-experimental inquiry into strategies used to recall the triads was unproductive. Most children stated that they were unaware as to how they remembered, they "just did." None reported conscious rehearsal of the triads while counting.

Comparison of these data with those reported by Murdock (1961) for adult subjects shows two interesting differences. Overall, the level of retention is markedly reduced in younger subjects regardless of delay interval or quality of hearing. The other point of interest is the fact that amount of recall in adults is a monotonic decreasing function while the data for children indicate a curvilinear function with better retention after 18 seconds than for

shorter periods of delay. It will be recalled that the amount retained after 18 seconds did not differ from that retained after only 3 seconds delay. Figures 3.1 and 3.2, for raw and transformed data, show that the curves for nearly all the groups rose from 12 to 18 seconds. Granted that the magnitude of the rise is small, it still cannot be easily dismissed if it appears with regularity as it does here. No explanation for this phenomenon is readily available. Artifacts such as response set of the subject must be ruled out since delay intervals were randomized and the subject had no prior knowledge concerning the duration of a particular delay. Only after he had passed the 12 second mark, so to speak, would he be able to realize that this was an 18 second interval, if he ever did consciously recognize the intervals. Furthermore, if retention at 12 seconds is depressed, how then does the subject revive the decaying trace to produce enhanced recall at a longer interval?

The finding that all groups of children recalled much less than did adults suggests that differences in the memory process as a function of age may be of greater importance than differences as a function of hearing ability. The data here are not unique. Haith, Morrison, Sheingold, and Mindes (1968) compared short-term memory in children and adults and found the storage capacity of children to be limited to two items. They used five-year-olds, much younger than subjects participating in this study. However, portions of these data reinforce their findings since the groups in this experiment also tended to recall two items of a triad more frequently than all three.

Perhaps the implicit auditory storage postulated for normal-hearing subjects is a strategy which depends upon wider experience with printed verbal materials than children tested in this study possess. These children may still be approaching stimuli concretely. They might view printed words as visual configurations rather than converting them to their aural counterparts. Perhaps, contrary to Sperling's (1963) thesis, visual information either can be stored veridically for fairly long durations or else can be rehearsed and returned to visual storage in subjects at this age level. It may be that visual information storage and visual rehearsal chronologically precede the auditory counterparts of these processes. Auditory information storage may be more efficient for language but may have to be acquired. With the development of the auditory information storage-rehearsal loop, the subject then may use this almost exclusively because of its efficiency to the detriment of his visual information storage skills. The critical factor which aids the auditory information storage process to gain supremacy may be the development of language skills. A good oral language is so used and so useful in our daily environment

that it soon surpasses all other stimuli in importance. Reading skills are elaborations of this basic process. Thus, all of us may start out visual and then become auditory later. Until the auditory "habit" becomes highly practiced, we may find instances of regression to the more primitive mode---visual---under stress. The short-term memory task used here may have been of sufficient difficulty to shunt even the "auditory" subjects (those with normal hearing) into using visual information processing systems. It should be noted that these children were not highly proficient in reading skills so that the visual-auditory transformation may not have been readily available under the temporal requirements of the task.

A visual store for information in younger subjects, of course, is not the only explanation for these data. Haith et al. (1968) acknowledged confusion concerning the processes involved in their study of short-term memory in adults and five-year-old children. "Possibly, children were reporting from a 'visual memory' with a 2-item capacity whereas adults were reporting from a 'verbal memory' with greater capacity. However, there are data . . . suggesting some tendency of children even younger than those used here to code visual stimuli verbally." (Haith et al., 1968, p. 12). It may well be that normal-hearing children used auditory store as postulated initially but that their memory capacity is limited so that they are unable to derive full benefit from the efficiency of auditory processing.

Whatever the processes used by the various groups tested in this study, the limitation upon retention seems the same, regardless of hearing ability. Further research is needed to investigate the validity of some of the ideas presented here. This study has served to raise questions rather than providing definitive answers.

CHAPTER IV

CONCLUSIONS

The basic objective of this research project was to determine whether qualitative differences exist in the thinking processes of normal-hearing and hearing-handicapped children. As a secondary goal, the relative efficiency of retention of words for short intervals by hearing and hearing-impaired children was also studied. Two experiments were directed toward the major objective and a third examined short-term memory.

The results of these experiments support the hypothesized differences as a function of hearing ability although the data are not as clear-cut as one would like. Experiment 1 used materials which rhymed either auditorily or "visually" and a significant interaction between hearing ability and rhyming dimension was obtained. Further examination of the data showed that three of the four categories of hearing-loss subjects differed significantly in the rate at which they learned the different lists and all of the hearing loss categories learned the visual lists more rapidly than the auditory. The single normal-hearing group tested did not differ significantly in learning either kind of list. Experiment 2 used rhyming words to produce interference in learning and found that the list containing consistent pairings was progressively easier to learn as the magnitude of the hearing impairment increased. No differences among groups were found with the inconsistent pairings.

It must be emphasized that, throughout all three of the experiments, all materials were presented only visually. Subjects did not hear or say the stimulus-response pairs in Experiments 1 and 2, or the triads in Experiment 3, nor were they observed doing this covertly. Even in the oral responding conditions of Experiment 1, only the responses were vocalized and then only during the test trials. Thus, auditory storage, if it was used by any of the subjects, was not an artifact of the experimental procedures but would represent a choice or predisposition on the part of the subjects.

Certain aspects of the data from the three studies are inconsistent in some respects, or at least appear so

superficially. Experiment 1 found the group with very mild hearing losses (0-25 dB) to be most unlike normal-hearing subjects in learning auditorily rhyming lists while in Experiment 2 this same group (but different subjects) performed most like those with normal hearing. Should this discrepancy be dismissed with "further research is needed" or can some explanation be found to resolve this problem?.

Sampling differences can be fairly well ruled out almost immediately on the basis of the descriptive information summarized for the 0-25 dB group in Tables 1.1 and 2.1, unless one wishes to argue that those variables are not relevant to the task and some other dimension not examined is the basis for the difference. Also, as mentioned in Experiment 1, performance of the group in question was not out-of-line on the "visual" rhyming lists, thereby indicating a group by list interaction for that group. It was suggested there that the poor performance of the mild hearing loss group on auditory rhymes reflects their lack of auditory training. Although their hearing loss is minimal, it may still be sufficient to direct their attention away from the auditory dimension. Auditory training serves to re-orient the child to using the auditory dimension wherever possible.

The "inconsistent" behavior of the 0-25 dB hearing loss group may mean that they do not use their hearing unless they have to. Their modality preference is probably visual since this channel has less "static" in it. The usual recommendation of favorable seating in the classroom not only puts such a child in a better position to hear but, unfortunately, also puts him in a better position to see. Only when the task cannot be accomplished through visual means does he then turn to other sensory dimensions. Like the hearing child, he has the potential for sensory flexibility but he is less inclined to use it. How did we force him to use implicit audition in one task but not the other?

Perhaps the answer is that the 0-25 dB group did not use implicit audition in either task. A logical error might be committed in assuming that, since the 0-25 dB hearing group performed like the normal-hearing group in Experiment 2, they were using the same processes. The auditory rhyming lists of Experiment 1 and the inconsistent and consistent lists of Experiment 2 could be classified as neutral or control lists if the auditory dimension is ignored, since no other cues are directly available to facilitate learning. The 0-25 dB group performed more poorly on these "control" lists than on the visual lists in Experiment 1 showing that visual similarity was facilitating. In Experiment 2 both the inconsistent and the consistent lists were "control" lists so performance was equivalent.

Normal-hearing children, on the other hand, may have used audition throughout the two experiments. The visual lists of Experiment 1 can be mastered auditorily by distorting the implicit pronunciation of one of the words to create rhyming pairs (I do it myself in recalling the pairs). The bizarre pronunciation may have provided additional facilitation for learning the visual pairs, as suggested by the study of bizarre imagery as a mnemonic device (Persensky & Senter, 1969). This may also explain why the visual lists were easier than the auditory lists in the standardization of materials (Appendix A). When the normal-hearing subjects tackled Experiment 2 using implicit audition, they encountered acoustic interference which depressed learning. Thus, the similarity in performance between normal-hearing subjects and those with 0-25 dB hearing losses might be due in one case to interference from acoustic similarity and in the other case to learning lists of unrelated pairs. It may be merely by chance that these two effects produced the same mean correct responses for the two groups in Experiment 2.

The other groups tested, those with hearing losses greater than 25 dB, have even more reason to ignore the auditory dimension as a channel for information. Therefore, it would be expected that their performance would be like that of the 0-25 dB group. However, these individuals are given more specific rehabilitative training to enable them to make maximum use of their residual hearing. As the magnitude of the hearing impairment increases, the rehabilitation efforts increase also. Primary among these techniques is auditory training wherein the child is literally taught to listen. He is trained to attend to and discriminate among speech sounds in particular. He is generally also given extensive training in symbol-to-sound correspondence to aid him in his oral language production. Thus, he is well-trained to expect printed words to have aural counterparts. His experiences have made him conscious of something that normal-hearing persons accept without awareness, perhaps. Using the school environment for collection of the experimental data probably enhanced this learned approach to verbal material.

It is felt, on the basis of these data, that auditory training does not change the hearing-handicapped child into a normal-hearing child but that it does change him from a hearing-handicapped child who has had no auditory training. Experiment 1 in particular illustrates the inefficient use of the rhyming cues in the auditory lists by all groups classed as hearing handicapped. The magnitude of the difference between the number of trials needed to learn the auditory lists as contrasted to the visual lists was not always significant but the direction of the difference was always the same. The performance of the hearing-loss groups on the auditory lists might be viewed as highly correlated with the

amount of auditory training they presumably have had. The group with very mild losses (0-25 dB) have no training and performed the poorest; those with 26-65 dB losses have some auditory training and their performance was somewhat better; the 66-90 dB group has had extensive training and performed even better yet; the 91+ dB group also receives extensive auditory training but the magnitude of the hearing impairment is such that they are unable to benefit as much from it. Therefore, we see a reduced efficiency in learning the auditory lists by this group, relative to the other hearing-loss groups.

The data from Experiment 2 are amenable to this view. Acoustic similarity produces interference if this is the primary way that information is processed. "Similarity and interference must refer to the appropriate level of coding" (Crowder & Morton, 1969). But, if the printed words are first distinguished along some other dimension (e.g., they "look" different), then the interference is minimized as one identifies the sounds of the words as a secondary characteristic of the materials. The interfering dimension now becomes facilitating to subjects using this approach. Normal-hearing children were unable to circumvent the auditory processing of the words and so exhibited poor performance attributable to interference. Hearing-loss children processed the words in a different manner and were not subject, therefore, to interference. On the list of inconsistent pairings, "visual processing with an auditory overlay" did not aid learning because no cues to facilitate association were available. However, when the consistent list was approached in the same manner by the hearing-handicapped children, they found auditory cues facilitating for associating the stimulus-response words in direct proportion to the amount of auditory training they are assumed to have had.

It would seem that auditory training is highly beneficial and should be extended to all degrees of hearing loss. If these data are valid, one of the major effects of auditory training is to direct the hearing-handicapped child's attention to the relevance of auditory information. Apparently, the basic thinking processes are not altered by the auditory training experience. The hearing-impaired child still retains his basic unique approach to the hierarchy of information-carrying channels but these have now been elaborated upon or supplemented by auditory training.

It may be that the effects of auditory training differ in the various groups. Those with lesser hearing losses derive benefits from the training in terms of acoustic information; they may really learn to listen and make use of auditory information. The child with a profound hearing loss, however, has little residual hearing. Auditory training in

his case may provide little effectively useful auditory stimulation but it may serve to establish articulation patterns to accompany the processing of printed words. The possibility of confounding acoustic and articulatory processes has already been alluded to in Chapter I. As discussed there, Hintzman (1965) felt that articulation rather than audition was the coding dimension in short-term memory; Cole, Haber, and Sales (1968) felt that the two were confounded but that articulation is more important; while Wickelgren (1969) concluded that the issue has not been settled yet. These conflicting positions were derived from studies of normal-hearing subjects as were the majority of the short-term memory studies interpreted as evidence for aural encoding processes.

The data presented here may indicate that auditory memory is most important to hearing subjects and that articulatory memory may gain in importance as the degree of hearing impairment increases. Perhaps groups with intermediate degrees of defective hearing are using both codes while the group with profound losses may rely chiefly upon articulatory coding. The issue cannot be resolved on the basis of these data but, if further research supports this interpretation, then it may be concluded also that articulatory coding is less efficient than aural encoding. This statement is based upon the relatively poorer performance of the 91+ group on the auditory lists of Experiment 1 in spite of the auditory training which they had received.

The conclusions of Experiment 3 can be re-examined now that the findings from the other two studies have been integrated. One of the alternative explanations suggested there was that a visual storage might characterize the thinking processes of both normal-hearing and hearing-handicapped children since all groups showed similarly poor retention on the task. The data from Experiments 1 and 2 both seem to indicate that a rather inflexible or rigid auditory approach is adopted by normal-hearing subjects when faced with verbal material, while hearing-impaired subjects are equally fixed in using a nonauditory (probably visual) approach. On this basis, it seems reasonable to conclude that the two kinds of hearing ability involved different processes in Experiment 3 also. The two processes can be considered functionally equivalent since the performance level for the groups did not differ.

Apparently the memory capacity for younger subjects is rather severely restricted. Haith et al. (1968) remarked upon the two-item capacity of five-year-olds. The data for Experiment 3 extend this to older children and to hearing-impaired children as well. Eye-voice span studies have shown the span to be two words in the second grade as opposed to

spans up t seven words in adults, depending on the materials (Kavanagh, 1968, p. 83). Withrow (1968) examined retention in normal and deaf children using sequential and simultaneous presentations of stimuli varying in meaningfulness and several rates of presentation. In almost every condition, the percent correct responses was high for two items per trial and dropped off dramatically for three or more items per trial, again giving confirmation to the limited memory capacity of children both with and without impaired hearing. The ages of the children used in his study were not reported but, from the nature of the tasks and the levels of performance, it can be assumed they are at least as old as the subjects used in this project (about ten years and older).

In conclusion, then, the studies conducted to examine the hypothesis of qualitative differences in cognitive processes as a function of hearing ability have shown that such an hypothesis is tenable. Normal-hearing children and children with any degree of hearing impairment performed differently on the tasks in these experiments and these differences in performance can best be explained in terms of the hypothesized qualitative differences. Furthermore, the two classes of children (normal-hearing and impaired-hearing) were equally as proficient, or equally lacking in proficiency, in retaining verbal material for short intervals. The storage and retrieval processes may differ in the two groups but they resulted in equivalent levels of retention. Limitations on the memory capacity were found in both groups consistent with reports by others.

The results of this project have serious educational and rehabilitative implications:

1. On the basis of these findings, auditory training has been shown to be effective in modifying the verbal behavior of hearing-impaired children. The data suggest that even children with very mild hearing losses would benefit from auditory training. The assumption that their high degree of residual hearing renders auditory training unnecessary is not supported.

2. The evidence that qualitative differences in thinking occur as a consequence of a congenital hearing impairment suggests that educational techniques with the hearing-handicapped should be re-examined. To the extent that present procedures are drawn from normal-hearing experiences, they may be quite inappropriate for the hearing-impaired. The retarded language skills of the hearing-handicapped may be rectified with other different methods for teaching which would capitalize upon their cognitive structure. However, data presented in Appendix B suggest that the cognitive structure in the hearing handicapped might be modified under certain conditions. Further study is needed to clarify this point.

Additional research is indicated along several avenues as a result of this project. Research is needed to identify educational procedures which would be more effective for the hearing-impaired than those now being used. Further study of the functional equivalence of the different processes should be done. This is particularly important since demonstration of functional equivalence would suggest that the hearing-handicapped can arrive at the same educational goals as do children without hearing defects but by a different route. Also the immutability of these thinking processes should be explored. If further study indicates that the processes employed by normal-hearing individuals have some innate superiority in terms of functioning meaningfully in our civilization, then consideration must be given as to how, when, or even if we can change the nonauditory thinker into an auditory one. Appendix B presents data suggesting that such a change can occur but the conditions for it need exploration. It is also possible that qualitative differences similar to those identified here are the basis for the reading difficulties of so-called normal-hearing children (i.e., those labeled dyslexic). And finally the question must be asked "If a congenital hearing impairment produces qualitative differences in thinking, what are the effects of other sensory deficits upon cognitive processes? And, since a sensory deficit of any sort does modify the effective environment for the individual, what, then, are the effects of other altered environments, e.g., cultural deprivation, upon cognitive structure?"

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APPENDIX A

Standardizatization of Lists for Experiment 1

Two lists of auditorily-rhyming word-pairs and two lists of visually-similar word-pairs were generated to be used in Experiment 1. Each list was intended to be used alternately with its companion list in repeated testing of the same subjects under different conditions of responding. Therefore, it was necessary that the lists be equivalent in difficulty in order to avoid confounding list differences with modality-of-response differences.

Care was taken in the selection of the materials initially. The word pairs were all monosyllabic, of high frequency, and with minimal intra-pair associative strength other than the dimension of experimental interest. Furthermore, inter-pair similarity within a list was kept low as was similarity between lists. Then, as a further check on the adequacy of these procedures, the lists were administered to samples of subjects. Grade 4 classes were used since the subjects for this project were taken from this same level of achievement.

Method

The word lists have already been described in the text. The complete lists are found in Appendix B.

Twenty classrooms of grade 4 subjects participated in this portion of the study. Eight sections were from schools in the Detroit Public School System and the remaining 12 sections were from a suburban school system. The suburban community can be characterized as upper lower and lower middle class; the majority of the residents are employed in "blue-collar" and "white-collar" positions, the homes are "modest." The urban schools were not "inner city" but were more peripheral to that area. The same general description could be applied to these neighborhoods.

Written responses and group testing procedures as described in Chapter II were used. All lists were presented for a total of ten learning-test trials. Each classroom received only a single list to learn. A rigorous scoring criterion was used in which the responses had to be entirely correct in both spelling and position before being accepted. For example, if a subject missed an answer and then forgot to skip a space, his remaining answers would be misplaced by one and were scored wrong even if they were "right but off one space." The criterion score was the total number of correct responses for the ten trials.

Results

The data are presented in two sections for reasons that will become apparent. The first standardization data were

obtained from eight classes in the Detroit Public Schools. Table A.1 summarizes the performance of these samples for the four lists. The last column gives the results of the *t* test

TABLE A.1

Summary of Performance of Eight Urban Grade 4 Classes on Four Lists From Experiment 1

List	Sample	N	$\bar{X}$	SD	*t*
V-1	1	25	42.96	16.11	6.68**
	2	27	67.56	9.27	
V-2	1	32	58.53	13.32	3.91**
	2	30	42.80	18.14	
A-1	1	30	36.37	18.94	2.72**
	2	33	49.63	19.73	
A-2	1	28	66.20	8.79	2.24*
	2	34	59.71	13.05	

$^{**}p < .01$, $^{*}p < .05$

for the difference in means between samples. As shown there, none of the data for any list could be pooled. All differences between samples were significant at the .05 level or higher. No procedural reasons could be discerned for the lack of stability of performance on the lists. A similar lack of consistency in performance among supposedly similar samples had plagued us in Experiment 2 as well. Those classes had also been taken from urban schools.

It was decided to move to suburban schools and replicate the standardization before discarding the lists and beginning all over. The data from the suburban school system for the four lists are summarized in Table A.2. Three samples per list were used. Analysis of variance was performed for each list and, as shown in the last column of Table A.2, none of the lists had significant sources of variance attributable to classes. All of the *F* ratios are not significant.

The three samples for each list were pooled to yield a single estimate of the population parameters for each list. These new values are given in Table A.3 with the results of the *t* test for difference in means. As seen there, the two

TABLE A.2

Summary of Performance of Twelve Suburban Grade 4 Classes on Four Lists From Experiment 1

List	Sample	N	$\bar{X}$	SD	*F*
V-1	1	25	50.80	19.08	
	2	31	50.45	18.15	.52
	3	19	45.53	19.53	
V-2	1	26	53.77	17.23	
	2	29	53.69	18.46	1.60
	3	31	46.81	15.96	
A-1	1	30	40.63	20.79	
	2	25	40.64	19.76	.33
	3	26	36.81	19.03	
A-2	1	28	48.18	12.54	
	2	26	45.15	15.10	1.02
	3	25	42.16	18.20	

TABLE A.3

Pooled Suburban Data for Four Lists From Experiment 1

	List					
	V-1		V-2	A-1		A-2
N	75		86	81		79
$\bar{X}$	49.32		51.23	39.41		45.28
SD	18.69		17.34	19.75		15.34
t		.67			2.08*	

*$p < .05$

visual lists can be considered of equivalent difficulty since the difference in their means was not significant. The two auditory lists differed at the 5% level of significance. Also it is obvious that both visual lists are easier than

the auditory lists since higher mean correct responses were obtained with the visual lists.

Discussion

In view of the results from the suburban data, the equivalence of the visual lists was unquestioned. It was decided to accept the equivalence of the auditory lists since large samples were needed to achieve even the 5% level of significance. The lists do not differ if alpha is set at .01. Much smaller samples were used in Experiment 1.

The lack of consistency in the urban data is puzzling but is apparently "real" since the same effects were obtained with group testing in Experiment 2. The variance seems to be reflecting unique variations among the grade 4 classes rather than any procedural differences since stable performance was obtained with the suburban classes using the same materials and methods. On the basis of these findings, the remaining data for all three experiments were collected in suburban school systems.

The difference in difficulty between the visual and auditory lists was surprising. The lists had been constructed along dimensions which should have made them either equally difficult or, if any difference at all was predicted, it would be expected that the auditory rhymes would have been easier. Given the results, we did some "soul-searching" and arrived at several tentative explanations for the data:

1. The visual pairs were spelled alike with the exception of the initial phonemes. Spelling of the correct responses may have been facilitated by this fact, whereas the responses in the auditory lists had no such spelling cues. Use of a rigid scoring criterion may have penalized the auditory lists more than the visual. However, following examination of the data obtained in Experiment 1, this explanation must be discarded since we did not find a modality-of-cue by modality-of-response interaction. In other words, if the auditory lists had been made "harder" by the scoring rules, then the oral responding condition in Experiment 1 should have reflected this difference. The oral auditory scores should have been much better than the written auditory scores. Since this did not occur, this explanation was rejected.

2. As indicated in the "Materials" section of Chapter II, a few words were used in the lists which had Thorndike-Lorge frequency counts lower than A. However, the differences in lists did not parallel these differences in frequency. All the words in list A-1 were A or AA; all but two words (one stimulus and one response from different pairs)

were A or higher in list A-2. In contrast, V-1 had five words less frequent than A, four of them being responses, and list V-2 had all A and AA words. Thus, if frequency had been critical to performance, list V-1 should have been the most difficult and the two visual lists should have differed. Since this was not the case, this explanation was also rejected.

3. Perhaps the explanation for the difference between the visual and auditory lists can be found in the strategy used to learn the lists. As suggested in Chapter IV, the normal-hearing child may have used auditory imagery to learn the visual pairs as well as the auditory pairs. He may have distorted the pronunciation of one of the words in each pair to create rhyming pairs in the visual lists.

Had this been done, facilitation might be expected from two sources. McLinden (1959) had used a "combined" list of word-pairs in addition to "auditory" and "visual" lists. The pairs in the "combined" list both looked alike and sounded alike (e.g., BOAT-COAT). Learning in all groups was numerically better for this list than for the auditory or visual lists although not all differences were significant. Thus, the visual list might have been transformed into a "combined" list by changing pronunciation. Facilitation might be predicted from another source also. Converting the visual pairs into rhyming pairs produces bizarre or unique pronunciations of familiar words. Persensky and Senter (1969) found that bizarre imagery facilitated the learning of serial verbal lists. The different pronunciations may have enhanced the recall by adding additional cues for retention. The auditory word-pairs rhymed but generalization could produce many rhyming extralist intrusions. With the "distorted" rhymes, very few intrusions could occur which would fit the particular situation. Recall would be direct to the specific item.

This third explanation is tenable and consistent with the data. It cannot be rejected without further study.

Of course, the possibility remains that the word-pairs in the visual lists were in some yet unidentified way easier than the auditory pairs. For example, the intrapair associative strengths of the two lists have not been assessed but they could form a basis for the obtained differences. However, these possibilities seem less compelling when the data from Experiments 1 and 2 are viewed together. The fact that differences in performance in the two studies were found in the predicted directions as a function of hearing ability leaves the third explanation (distorted pronunciation) as the most feasible.

APPENDIX B

Visual Interference and Hearing Ability

As discussed previously, formal similarity is one of the major experimental variables in this project. Experiment 1 examined the effects of using either acoustically similar or visually similar word-pairs in a paired-associate task. Children with hearing impairments found the acoustically similar lists to be more difficult than did children with normal hearing. Experiment 2 employed acoustic similarity in an interference paradigm and showed that children with normal hearing performed more poorly than did children with hearing losses on one of two lists which differed only in the manner of pairing. The improvement in paired-associate performance with increased hearing loss was significant. These data were interpreted as supporting the basic thesis that normal-hearing and hearing-handicapped children use qualitatively different processes for storing and retrieving verbal material.

That subjects with normal hearing use some acoustic or auditory storage process is suggested by the interference exhibited in Experiment 2. However, the basis for the storage process used by hearing-handicapped subjects is not so clear, other than a conviction that it is "not auditory." It has been assumed that, after the phonetic properties of a word, the next most compelling dimension is the appearance of a word. This conclusion is derived, in part, from studies of formal similarity using normal-hearing subjects. In general, the literature indicates that formal similarity (letter duplication) interferes with learning but only when meaningfulness is low; with highly meaningful material, formal similarity no longer plays a role in acquisition. While these studies have not been replicated with hearing-handicapped subjects, they do provide evidence that visual properties serve as an alternate dimension for processing printed material, at least for normal-hearing subjects under certain conditions. The fact that the deaf do not demonstrate the same problems with spelling as seen in normal-hearing persons (Templin, 1948) lends support to the assumption that the deaf might select the visual aspects of printed material for attention.

This study was designed to test the hypothesis that the deaf use visual characteristics of words in storage and retrieval. Thus, it constitutes the first direct test in this project of specific dimensions which may be used by subjects with impaired hearing; up to this point, only inferential data have been obtained. In order to determine whether it is in fact the visual dimension which is relevant for hearing-impaired subjects, the design for Experiment 2 was modified so that the appearance of the material was now the source of interference. If spelling or other visual attributes of the materials serves as the basis for memory in hearing-loss subjects, then relative interference with

learning should be observed analogous to that demonstrated in Experiment 2 for normal-hearing subjects and acoustic similarity.

Method

One of the visually similar word lists from Experiment 1 (list V-1) was rearranged to form two lists, one with consistent pairings (VC) and another with inconsistent pairings (VI) as had been done with the rhyming lists for Experiment 2. The four-pair practice list was also used. The complete lists appear in Appendix C.

A total of 64 subjects was tested in this portion of the project; 40 were enrolled in grade 4 classes in a suburban school while the remaining 24 were obtained from a day-school program for the hearing handicapped in a nearby community. Normal-hearing data for the two lists from Experiment 2 were also obtained; this was done to verify the level of normal-hearing performance under conditions of individual testing. A number of grade 4 children had to be eliminated from the study for not grasping the task requirements. Among the hearing-handicapped children tested in this experiment were several with reading levels greater than 6. These were tested at the request of the supervisor of their educational program and were not included in the analyses. The final numbers of children whose data were used in this portion of the project are 12 normal-hearing and 15 with hearing impairments of 66 dB or greater for the better ear. An additional 13 grade 4 subjects learned the Experiment 2 lists containing acoustic similarity.

A modified Patterson S-Pa memory drum, Model 1-B, was used to present the materials in this study. This instrument consists of a rotating cylinder which holds a continuous tape upon which the materials were typed in upper case letters. The stimulus and response words were presented sequentially. Each advance of the cylinder brought either a stimulus word, a response word, or a blank space into view through a 3/4-inch square aperture. The temporal parameters of presentation were the same as for Experiment 2; i.e., 2 sec for stimulus, 2 sec for response, and 2 sec for blank interpair interval during study trials, with a 2 sec stimulus presentation followed by a 6 sec blank interitem interval during test trials to allow time for the subject to respond. Subjects wrote all responses in booklets.

A total of 12 study trials alternated with 12 test trials. The four-pair practice list was administered to all subjects prior to the experimental list to reduce "learning to learn" variance. Each subject learned only one experi-

mental list. All testing was done individually as described previously. The memory drum procedure can be considered to be functionally equivalent to the Tel-n-See procedure in all important respects. However, to reduce the length of the tape loop to manageable proportions, only two randomizations of study trials and of test trials were used as compared to three different orders for each in all studies using the Tel-n-See.

Results

Table B.1 presents the mean number of correct responses over 12 trials for each group with the two new lists, VC and VI. As shown there, the two normal groups performed at

TABLE B.1

Summary of Performance of Normal and Hearing-Loss Groups on Two Lists Containing Visual Similarity

Group		List: VC	List: VI
	$\bar{X}$	27.17	30.50
Grade 4	s	17.38	17.87
	N	6	6
	$\bar{X}$	47.38	55.43
66+ dB	s	23.41	25.05
	N	8	7

a much lower level than did the hearing-impaired groups and pairings did not seem to make a difference. These conclusions were verified in a 2x2 analysis of variance which found hearing ability to be the only significant source of variance, $F(1,23)=7.30$, $p < .05$. Thus, the hearing-loss group performed overall at a significantly higher level than did the grade 4 subjects.

The two groups of grade 4 children who learned the lists from Experiment 2 seemed to perform somewhat differently from either the grade 4 subjects tested in classroom-sized groups without use of a practice list or the 0-25 dB hearing-loss group who were tested individually with a practice list. Table B.2 summarizes the data for these three groups for the

two lists from Experiment 2. The lists have been re-labeled AI and AC (previously I-1 and C-1, respectively) to emphasize the fact that acoustic similarity is being manipulated as

TABLE B.2

Comparison of Three Groups on Two Lists Containing Acoustic Similarity

List		Group Grade 4 (Classes)	Grade 4 (individual)	0-25 dB (individual)
	$\bar{X}$	43.10	27.86	48.54
AI	s	19.77	11.82	24.18
	N	10	7	11
	$\bar{X}$	34.60	37.67	35.30
AC	s	21.64	29.90	23.02
	N	10	6	10

opposed to visual similarity in the new lists. However, the apparent trend to better performance with consistent than with inconsistent pairings obtained with grade 4-individual testing, while consonant with Dallett's evidence (1966), is not statistically reliable and is not observed in the other two groups. A 2x3 analysis of variance of the data showed no significant sources of variance. Therefore, at this time no credence can be placed in this phenomenon although further study with this age group is indicated.

Discussion

The results of this study, using physical appearance of words as a possible source of interference, failed to show any difference as a function of hearing loss. On the basis of these data, the visual dimension can be ruled out as a basis for the internal processing of words by subjects with congenital hearing impairments. However, other factors must be considered before these results are generalized to all subjects with hearing losses.

Qualitative differences in the dimensions of memory were postulated initially as a possible explanation for the limited verbal skills of the hearing impaired. In general,

a congenital hearing loss hampers the acquisition of language in direct proportion to the degree of the impairment. The children with hearing losses who participated in this study, however, were atypical in that they are quite proficient verbally. They make good use of their residual hearing for listening; they communicate even with one another orally; their reading levels are more consistent with their ages and do not show the ceiling effect at the grade 4 level. The differences between these children and others with similar degrees of hearing impairment who had been tested previously was obvious to the experimenters.

It may well be that these hearing-handicapped children are not employing memory processes different from those used by normal hearing children, contrary to the hypothesis. The fact that they have good language skills argues against the hypothesis. Furthermore, the levels of performance on the experimental lists suggest that they are functioning more like subjects with normal hearing, either by using different processes or by using the same process. These data suggest that the same process might be involved. In other words, the two groups of children may differ in hearing ability but may not differ in storage and retrieval processes. The superior performance of the hearing-handicapped might reflect greater test sophistication since they have served as subjects for other studies as well as being tested frequently in their school program. In general, hearing-handicapped children in any program have had many more experiences with different evaluative situations than have their normal-hearing counterparts.

If this interpretation is correct, that the particular hearing-loss children tested here are really functioning like normal-hearing children, then it also seems that the "normal mode" <u>can</u> be established with proper training. Demonstration of qualitative differences, as accomplished by this project, is only the first step. It serves to identify the basis for the limited language skills of the hearing impaired. The next step is to identify means of correcting this language deficit, either by changing the basis or by capitalizing upon it. It seems, from this sample of children, that good language skills can be developed in the hearing-handicapped and that it is probably accompanied (or preceded) by the establishment of a storage and retrieval system for verbal material that is similar to that used by normals. This study should be replicated with other groups of hearing-handicapped both language-proficient and language-deficient, to see if regular differences occur as a function of verbal skills. Certainly, the findings from this study cannot be generalized to all hearing-loss children in view of the many discrepancies between this sample and other samples with the same magnitude of hearing impaired. Of course, the other

possibility still remains, i.e., perhaps the visual dimension is not the critical one for hearing-handicapped subjects. Further research will establish the validity of these explanations.

APPENDIX C

Specific Materials Used in the Experiments

Stimulus-Response Pairs for the Lists Used in Experiment 1

Practice List	Auditory List 1	Visual List 1
paid - soft	weigh - play	done - gone
rock - jump	laugh - half	said - maid
boat - dress	more - door	snow - cow
lake - book	bear - care	hear - wear
	eight - rate	fall - shall
	lie - sigh	lose - rose
	meet - seat	home - some
	style - while	push - rush

Auditory List 2	Visual List 2
blow - toe	blood - mood
nine - sign	new - sew
could - wood	cave - have
gate - wait	though - cough
buy - fly	put - cut
tea - key	love - stove
soap - hope	lost - most
blue - two	how - know

Stimulus-Response Pairs for the Lists Used in Experiment 2

Set 1

Inconsistent (I-1)	Consistent (C-1)
door - sigh	door - sigh
play - style	play - while
bear - half	bear - half
eight - lie	eight - seat
care - seat	more - lie
rate - laugh	weigh - style
weigh - meet	care - laugh
more - while	rate - meet

Set 2

Inconsistent (I-2)	Consistent (C-2)
nine - wait	nine - buy
soap - could	soap - two
tea - fly	tea - could
blow - wood	blow - gate
key - two	sign - fly
toe - gate	hope - blue
hope - buy	key - wood
sign - blue	toe - wait

Stimulus-Response Pairs for the Lists Used in Appendix B

Visual Consistent (VC)

cow-rose
gone-push
hear-maid
fall-some
snow-lose
done-rush
wear-said
shall-home

Visual Inconsistent (VI)

snow-rose
hear-maid
done-push
shall-said
wear-home
fall-lose
gone-some
cow-rush

Word Triads Used in Experiment 3

PRACTICE

west	class	get
up	bag	go
good	just	place
pair	gave	floor
one	not	page

TEST

fat	hall	come
bed	hand	fall
club	great	dose
fail	bird	clear
had	might	fair
bad	must	fruit
sea	done	game
tell	drink	light
food	born	touch
add	dog	keep
act	far	blow
draw	bum	yet
boy	few	step
hot	been	art
camp	mark	feel
bring	dark	true
care	day	mile
full	came	ice
take	beat	as
bank	move	low
ball	cloud	late
build	are	caught
door	cry	book
job	queen	and
chair	does	pick
will	clean	glad
when	sold	drive
eye	cent	view
free	made	part
flow	it	cross

TEST

knew	gate	life
hill	saw	for
deep	off	but
did	arm	best
man	blue	ear
found	rate	king
dead	five	post
near	cut	hold
girl	since	east
safe	more	felt
sore	fire	rich
fast	meat	here
boat	cost	fill
end	moon	sail
child	base	all
red	in	dear
bell	green	dry
hat	both	down
eat	back	air
price	blood	check
mind	bill	face
chief	year	wait
vote	from	be
neck	own	am
sell	big	do
board	age	less
buy	feet	cook
could	fear	cup
can	brown	cool
bay	home	drop
sun	egg	fly
call	edge	leg
land	case	room
wood	gone	dress
charge	ash	pull
coat	prove	black